AGRONOMY FACTS

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COMPOSITION OF SOIL AIR

In field soils, from 10 to 35 percent of the soil volume is normally composed of gases. The composition of this soil atmosphere may have significant effects on chemical reactions, microbiological activity, and root behavior in the soil. Rather wide variations occur in the composition of the soil atmosphere as a consequence of changing environmental conditions or soil management practices. Knowledge of the factors that contribute to such changes and information concerning their effects on soil and plant behavior are useful in understanding certain soil management problems.

As a first approximation, the air found in field soils is similar to that of the atmosphere above the soil surface. It will normally contain about 20 percent of oxygen and 78 percent of nitrogen on a volume basis. The concentration of carbon dioxide, however, is usually from 10 to 1,000 times the .03 percent found in the atmosphere. The amount of water vapor in the soil air is within 2 percent of complete saturation at all times in field soils that are moist enough to permit plant growth. Under severe anaerobic conditions such as are found in submerged soils, significant amounts of methane, hydrogen sulfide, and hydrogen may accumulate. The concentrations of such gases in field soils is below the detection level.

The composition of the soil atmosphere undergoes rather definite changes with depth of soil and with season. Although these changes may be modified by other environmental or cultural factors, it is usually true that in the rooting zone the percentage of oxygen decreases and the percentage of carbon dioxide increases with depth below the soil surface. The percentage of oxygen in the soil air at any given depth is usually lowest during the late spring and early summer, when soil microbial activity is at its maximum level. A secondary minimum may occur in early fall and in well-drained soils is commonly followed by a maximum percentage of oxygen in the late fall and winter. The seasonal variations in carbon dioxide are the inverse of those of oxygen.

The variations in percentages of oxygen and carbon dioxide in the soil air are caused by the simultaneous action of two sets of processes. The first of these processes is the chemical and biological reactions that occur in soils that utilize oxygen and liberate carbon dioxide. These reactions tend to magnify the differences in percentages of oxygen and carbon dioxide between the soil air and the atmosphere. Operating simultaneously and in the opposite direction are the physical processes of gas movement, which tend to keep the composition of the soil air and the atmosphere the same.

Therefore the actual composition of the soil air at any particular time and place will be different from or similar to that of the atmosphere, depending on the relative effectiveness of these two sets of competing processes. Thus, if gaseous interchange between the soil and the atmosphere above it is restricted and the level of biological activity in the soil is high, the oxygen content of the soil air will drop well below the normal 21 percent found in the atmosphere and the carbon dioxide content will increase to several thousand times the atmospheric level of .03 percent.

On the other hand, if biological activity is at a low ebb due to low temperatures or other causes and if there is a rapid interchange of gases between the soil and the atmosphere, then the oxygen

and carbon dioxide content of the soil air will be very similar to that of the atmosphere.

Diffusion is the principal mechanism by which oxygen and carbon dioxide move into and out of the soil. The rate at which these gases are transferred is determined by the amount of air-filled pore space in the soil and by the difference in concentration of oxygen and carbon dioxide in the soil air and the atmosphere. In the range of porosities commonly found in field soils, the rate of gaseous diffusion is directly proportional to the volume of air-filled pores. For this reason soil management practices that increase the air-filled porosity of the soil favor rapid diffusion of carbon dioxide out of and oxygen into the soil and maintain good aeration conditions.

M. B. Russell
10-11-54

AGRONOMY FACTS

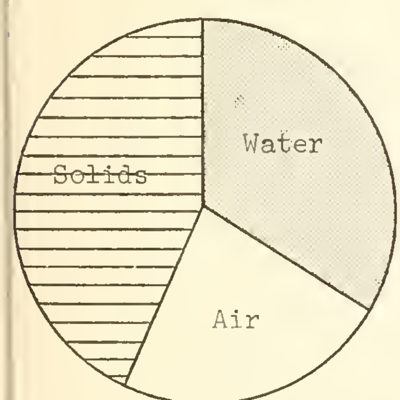
SOIL POROSITY AND AERATION

Roots of crop plants are living organisms that require an adequate supply of oxygen to grow and to absorb nutrients and water. In addition, most soil microorganisms require oxygen for normal metabolism, and many chemical reactions in soils are affected by the composition of the soil atmosphere. For these reasons soil aeration has an important influence on soil and plant behavior. Many soil management practices produce desirable results through their effects on soil aeration conditions.

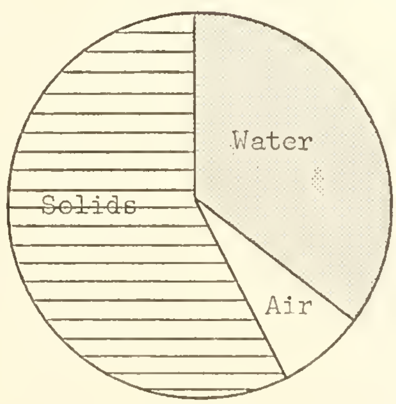
Before we can logically discuss the effects of soil aeration on soil and plant behavior, we must have some way of describing and measuring this property. The simplest way to describe soil aeration is in terms of the amount of air contained in a unit volume of soil. A given volume of a field soil will contain solids (sand, silt, clay, organic matter), liquids (water), and gases (oxygen, carbon dioxide, nitrogen, etc.) in various proportions. The following diagrams show how the volumes of these three components may vary in a silt loam soil.

In soils that are well granulated, the solid constituents usually occupy somewhat less than 50 percent of the total soil volume. The remaining, or pore-space, volume is occupied by either air or water. If the soil is saturated, all pores are filled with water and the aeration porosity is zero. As such a soil loses water by drainage or by surface evaporation, the largest soil pores are the first to drain and become filled with air. For this reason the large pores are more important than the small ones in providing air for growing roots and the aerobic soil microorganism.

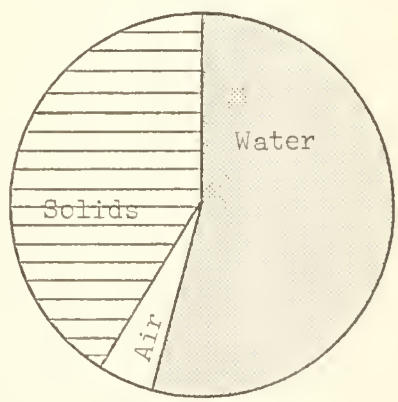
It is customary, therefore, to divide the total pore-space volume into two parts based on the size of the individual soil pores. Thus soil porosity is commonly described by the percentage of total soil volume made up of "noncapillary pores" and "capillary pores." The former represent the larger pores, which are most important in soil aeration and rapid water drainage. The latter represent the small pores, which do not drain readily and which provide the water storage capacity of soils.



Well-drained,
good tilth



Well-drained,
compact soil



poorly drained,
good tilth

Both adequate aeration and good moisture storage capacity are necessary for abundant plant growth. For this reason it is desirable to have a good balance in pore sizes in field soils. Although it is not possible to specify precise limits at this time, it seems that 15 to 20 percent of the large noncapillary pores and 35 to 45 percent of the small capillary pores represent nearly optimum soil tilth for soils of intermediate texture, such as the silt loams.

Coarse-textured soils will usually have higher noncapillary and lower capillary porosities than those mentioned above. For this reason inadequate water storage capacity rather than inadequate aeration is the most common physical problem. Management of such soils should therefore emphasize the conservation and efficient use of soil moisture rather than the increase of soil aeration.

Fine-textured soils, such as the silty clays and clay loams, will usually have lower percentages of noncapillary pores and higher percentages of capillary pores. Consequently such soils are likely to suffer from inadequate aeration rather than from inadequate moisture storage capacity. Management of these soils should emphasize practices that reduce soil compaction and increase aggregation, because both of these phenomena increase the volume of large pores.

M. B. Russell
10-18-54

AGRONOMY FACTS

APPLICATION OF GENETICS TO BREEDING BETTER PLANTS

Man depends upon plants for his food, his shelter, and his general well-being. All of us know that adequate water, mineral elements, light, soil structure, etc., are important in producing high yields. And, consciously or unconsciously, we know that the heredity of our crop plants is also important in determining how high yields will be.

Man's early attempts to improve plants were based upon superstition. Progress was slow. However, in 1900 the experiments of Gregor Mendel, an Austrian monk, were rediscovered. Mendel had experimented with inheritance in the common garden pea and published his findings in 1865. After the attention of biologists had been called to these experiments, a great deal of work on heredity was started in many plants and animals. Fortunately, work on inheritance in corn was increased. Hybrid corn was a by-product of this experimentation.

What were the fundamental principles that Mendel discovered?

Dominance. Mendel found that contrasting characters, such as red versus white flower color, when brought together in a hybrid, differed widely in their ability to express themselves. A pure-breeding red-flowered variety crossed with a pure-breeding white-flowered variety produced only red-flowered progeny. In this example red color is said to be dominant and white flower color is said to be recessive. The product of the cross is said to be a hybrid. Hybrids are therefore the offspring of two parents that are unlike one another in one or more heritable characters.

Segregation. When the red-flowered hybrid plants are intercrossed and the resulting seed is planted, part of the plants produce red flowers and part produce white flowers. Schematically, the inheritance can be explained in this way:

Let R represent the dominant character (red)

Let r represent the recessive character (white)

Red R/R x White r/r

Red hybrid R/r

R/r x R/r

1 R/R)
2 R/r)-- Red

1 r/r)-- White

As you can see, the second generation produced by intercrossing the first generation hybrids resulted in a 3:1 segregation. Literally, segregation means "separation." The factors that determine flower color are separated, or segregated, during reproduction and hence maintain their identities.

Plants that are pure-breeding are said to be homozygous (R/R and r/r). Those that will produce both red-flowered and white-flowered progeny are said to be heterozygous (R/r). Humans are doubtlessly heterozygous for many characters, or else the children in a family would all be alike in appearance, intelligence, and other characteristics.

Independent assortment and linkage. Mendel found that different characters in the pea were transmitted from generation

to generation as if they were independent entities. This process is illustrated in the inheritance of endosperm quality and color in corn:

Let S represent dominant starchy endosperm
Let s represent recessive sugary endosperm
Let Y represent dominant yellow endosperm
Let y represent recessive white endosperm

Yellow starchy YYSS x White sugary yyss

Yellow starchy hybrid
YySs

YySs x YySs

9 yellow starchy
3 yellow sugary
3 white starchy
1 white sugary

If the factors for kind of endosperm (sugary or starchy) and color of endosperm (yellow or white) had not been independent, then a ratio of three yellow starchy kernels to one white sugary kernel would have resulted. Also, new types (yellow sugar and white starchy) would not have appeared. Independent assortment of factors permits the establishment of new types in crop plants. The combination of certain desirable characters from one parent with the most desirable characters from another parent is the constant goal of plant breeders.

Certain factors (genes) do not assort independently. It has been found that these factors are held together in strands called chromosomes. The closer together genes are on the chromosome, the less the chance that they will assort independently. Factors that do not assort independently are said to be linked. Plant breeders often find that certain desirable factors are linked with undesirable factors, and they have expended a great deal of effort to separate the desirable factors from the undesirable ones.

Under what circumstances are these principles applied to practical problems? Dr. O. T. Bonnett cites this case in wheat breeding:

Rex White beardless rrBB x Illinois 2 Red bearded RRbb

Red beardless hybrid
RrBb

RrBb x RrBb

9 red beardless
3 red bearded
3 white beardless
1 white bearded

One family of the red beardless group was particularly outstanding for yield and straw quality. This new type is designated as 45-553. The red color of grain from the Illinois 2 parent and the beardless character of the Rex parent are combined into a new variety. This new variety is susceptible to rust and is not usable itself. However, it is being used as a parent of new varieties because of its fine straw quality.

Plant breeders are able to produce new varieties efficiently through the application of genetic principles to their breeding programs. In this way new superior varieties can be created that combine the best qualities of the parent strains.

D. E. Alexander
10-25-54

AGRONOMY FACTS

BROOMCORN IN ILLINOIS

Broomcorn production in Illinois is confined mainly to a relatively small area including the three counties of Coles, Douglas, and Cumberland. The crop is grown for two purposes, brush and seed. The brush is sold to manufacturers for making brooms, and the seed is sold to growers in Oklahoma, Texas, Colorado, New Mexico, and Arizona, as well as in Illinois, for raising broomcorn.

Illinois is suited to the production of high-quality seed because of its favorable soil and climate and the ability of its producers to maintain purity of seed through isolation and selection.

In 1954 Illinois had an estimated 3,500 acres of broomcorn, with a total production of 1,100 tons, or 628 pounds an acre. No information is available on total production of seed or per acre yields.

Growing the crop. Broomcorn needs a well-prepared seedbed. The seeds are small and should be planted at a uniform depth in order to get uniform germination and ripening. The seedlings grow slowly at first, giving weeds an undue advantage. Treating the seed with a thiram compound or other suitable fungicide will help to control seedling blight and smut. Rolling after planting will help to pack the soil around the seed and insure uniform germination. During seedbed preparation it is sometimes possible to kill a crop or two of weeds before planting.

Broomcorn is a warm-weather crop. The soil should be warm when the seed is planted; hence the best time to plant is usually after corn (between May 10-15 and June 1).

Since the seed is small, it goes a long way in planting. One bushel will be enough for about 20 acres. It should be drilled in rows 40-42 inches apart and at a rate that will space the plants 3-5 inches apart in the row.

The crop is cultivated in the same way as corn and with the same equipment, but shallow cultivation is important to avoid injuring the roots.

Both standard and dwarf varieties are grown in Illinois. The standard varieties are tall, ranging from 7 to 9 feet; the dwarf varieties are short, ranging from 4 to 6 feet. These varieties were in the preliminary list for certification in 1954[1]:

Standard	Total Acreage
Black Spanish	208 1/2
Illinois Favorite	1 1/2
Okaw	4
Tennessee Evergreen	3/4
White Italian Head 49	10
Dwarf	
Pfeifer Dwarf Head 125	20
Rennels Dwarf No. 11	349
Scarborough No. 7	50

Harvesting. Time to harvest is determined by the color of the brush. The fibers should be green from tip of head to base. When the brush is at the right stage for harvesting, the seed is usually in the milk or soft-dough stage. If harvesting is delayed too long, the brush becomes brittle and may lose its green color, becoming red or otherwise discolored. Both harvesting and subsequent handling should be pointed toward retaining the green color of the brush because it adds greatly to the market value of the crop.

1/ Field Seed Certification Guide, Illinois Crop Improvement Association, 1954 crop.

Harvesting standard broomcorn requires a good deal of hand labor. Many men work on a field at the same time. Each man works on two rows at a time, making what is called a "table" to lay the heads on as they are cut off. Walking backward, he grasps several stalks in both hands, first on one row and then on the other, breaks them about waist high, and bends them forward and across the opposite row, forming a table. He then cuts off the heads and piles them on the table, from which they are hauled in on "dump" wagons, run through a thresher to remove the more or less immature seed, and laid on racks in the drying shed to cure.

After the brush is dry, it is pressed into bales weighing around 300 pounds, and the crop is transported in this form to the warehouse or broom factory.

If broomcorn is grown mainly for seed, it is allowed to stand until the seed is mature. By that time the brush is overripe, but it still has some value if properly cared for. When the crop is harvested for seed, the plants are tabled as described above and the heads are hauled in on "dump" wagons. They are not threshed immediately but are laid on racks in the drying shed to dry before threshing.

Diseases. Anthracnose is the worst disease attacking broomcorn in Illinois. There are two phases, the leaf phase and the stalk phase. The disease appears first on the lower leaves as a leaf spot, but later it may enter the stalk. On leaves it destroys the tissue and later the whole leaf dies. On stalks it rots the interior, causing the plant to lodge and die prematurely. In plants that die prematurely, the brush is brittle, making it useless for brooms. The only known way to control anthracnose is to breed resistant varieties. There are other diseases that attack and destroy the leaves of broomcorn, but they are not usually so serious as anthracnose.

In all of the varieties listed previously except Okaw and Rennels Dwarf No. 11, the leaves, leaf sheaths, and brush turn red when injured by insects or diseases. Okaw and Rennels Dwarf become tan when so injured. Okaw is resistant to anthracnose leaf and stalk rot, and its tan color is believed to be associated with resistance. However, the association is not complete, because Rennels Dwarf No. 11 is susceptible and there are resistant reds as well as other susceptible tans. Tan plants are also desirable because their brush fibers remain green or dry to a tan or straw color that takes the stain well in broom-making. Reddish fibers do not stain well.

Insect pests. In Illinois the most common insect pests of broomcorn are aphids and chinch bugs. Aphids usually work on the brush and are most numerous inside the boot at the base of the head. In varieties that turn red, they cause the fibers to become reddish; as pointed out above, this red color is objectionable. In varieties that change to tan, the fibers become tannish; the tan color is less objectionable than the red. So far as is known, there are no varieties that are resistant to aphids, although normally those in which the heads extend above the boot are not attacked or are attacked only slightly. Miller Dwarf (Pfeifer Dwarf Head 125) is a good example.

Chinch bugs in large numbers are extremely destructive to broomcorn. They can be controlled by spraying, but no varieties are known to be naturally resistant.

One ton to three acres may be considered a fair to good yield for broomcorn. Prices vary widely depending on the quality of the brush and the supply and demand. The present price range is $300 to $500 a ton. The fact that so much hand labor is required adds to the growing cost.

C. M. Woodworth and
Benjamin Koehler
11-1-54

AGRONOMY FACTS

POLYPLOIDY AND PLANT IMPROVEMENT

Plants and animals ordinarily possess two sets of chromosomes, one set being inherited from the father and one from the mother. Under special circumstances plants may possess extra sets of chromosomes. Many of these types are of no use to man, but some of them, particularly in rye, in red clover, in alsike, and in sugar beets offer promise from an agronomic standpoint.

Plants that possess more than two sets of chromosomes are called polyploids. If the chromosome number of a plant carrying two sets of chromosomes, a diploid, is doubled, a kind of polyploid is produced. This type, called a tetraploid, has four sets of chromosomes. Tetraploids are of most interest to the plant breeder, although higher polyploid types can be produced experimentally.

Tetraploids are produced by plant breeders by carefully treating seed, or more commonly, by treating the growing point of a plant, with a chemical called colchicine. This drug apparently inhibits cell division. Chromosomes duplicate themselves in the treated cells, doubling the number of sets. These cells continue to grow and divide in a normal fashion. All tissue produced from them is tetraploid. In red clover these tetraploid sectors can be propagated by cuttings, increasing the number of plants available for seed production in the early generations of the work.

Seed borne on tetraploid plants also is tetraploid, provided the pollen parent also is tetraploid, Tetraploid flowers fertilized with pollen from a diploid plant produce shriveled, rarely viable seeds called triploids. In this example, two sets of chromosomes were inherited from the mother and one from the father. Tetraploids of cross-pollinated plants, such as rye or corn, must therefore be isolated from diploid fields if the maximum amount of seed is to be harvested.

What are the characteristics of tetraploids?

Yield. Swedish workers compared a good diploid variety of red clover with 15 new tetraploid varieties. In 11 out of 15 comparisons, the tetraploids outyielded the diploid variety. But the tetraploid varieties were somewhat slower growing in the early spring and were outyielded by the diploid at the first cutting.

The Swedish workers also compared diploid rye varieties with their tetraploid counterparts. On the basis of one year's trial, the tetraploids outyielded the diploids by 13 percent.

A yield trial at Urbana in 1954 compared a number of adapted diploid varieties with Tetra Petkus, a German-bred tetraploid rye. The tetraploid was not superior to the diploid varieties in yield of grain, but it was considerably stiffer strawed. Since it is unlikely that the diploid ancestor of Tetra Petkus is adapted to Illinois conditions, the tetraploid cannot be expected to be adapted. The lower yield of the tetraploid probably is due to its lack of adaptation rather than to its higher chromosome number.

(Continued on other side)

Size of parts. Tetraploids can usually be identified by gross features, such as thickness of leaf, width of leaf, size of stem, and seed size. The tetraploids are usually larger and have thicker stems than diploids. On the average, tetraploid rye kernels weigh 50 percent more than diploid kernels.

Fertility. Tetraploids usually set fewer seeds per plant than diploids of the same species. This failure is brought about by defective divisions of cells which produce eggs or pollen. Breeders have been able to improve seed set by selection. However, artificially produced tetraploids have not been found that have a 100 percent seed set.

An interesting type of tetraploidy is brought about by crossing species and doubling the hybrid. Triticale is a tetraploid of this kind. It has 14 rye chromosomes (two sets) and 42 wheat chromosomes (two sets). Triticale types producing up to 90 percent as much seed as good wheat varieties have been bred in Sweden. Such a high yield in a synthetic species is encouraging. It is likely that much more work of this kind will be carried out by plant breeders.

Tetraploid strains of corn have been in existence for a number of years. These strains are typically thick leaved and have poor seed set. Such strains cannot be directly compared with modern hybrid corn because they were produced by doubling nonadapted, weak genetic stocks. A means of producing tetraploids by genetic means has been recently devised. Large numbers of tetraploids can be easily produced by this method. Experiments are now under way that will permit eventual comparison of agronomic material at the tetraploid level with diploids from which they were derived.

Science has given the plant breeder a means by which numbers of sets of chromosomes may be varied within a species. Furthermore, new species can be created in certain circumstances by combining the chromosome sets of already existing species. There is little doubt that this new tool will be useful in breeding better plants for tomorrow.

D. E. Alexander
11-22-54

AGRONOMY FACTS

THE MECHANISM OF ION ABSORPTION BY PLANTS

Plant growth is to a large extent governed by the concentration of twelve essential nutrient ions in the tissues. Some ions, like nitrate, phosphate, and potassium, are needed in large quantities; others, like copper and boron, are needed only in trace amounts. With less than optimal concentration of any of these ions, growth is restricted.

The source of these required ions is in the soil. A fertile soil provides ample amounts of them in reasonable balance. But ions in the soil do not directly support the growth of plants. To promote growth, they must pass into the plant. Thus between the supply of nutrients in the soil and the concentrations needed by the plant for growth lies a key physiological process--the process of ion absorption. It is a process that functions optimally only in a fertile, moist, well-aerated soil.

The Anatomy of Absorption

The plant cell is the basic unit of plant life. The growth and reproduction of the plant is but the sum of the growth and reproduction of its cells. Similarly, the ion accumulation by a plant is but the sum of the ion absorption of its component cells. The initial absorption is carried on by the surface cells of the root, which are in contact with the soil water and clay particles. Underlying cells use these surface cells as a source of supply and in turn absorb ions from them. Thus ions can be passed from cell to cell through the root tissue.

In the central core of a root are the vascular elements (xylem or wood), which carry water upward to the aerial portions of the plant. A ring of specialized cells surrounds this conductive tissue and secretes nutrient ions in the upward-moving water. The mechanism of ion secretion--the opposite of absorption--is not understood. Like absorption, it is an "active" process, dependent on the energy released in respiration, and it proceeds optimally only in well-aerated roots. It appears that water passing through the root helps to move some ions, like calcium, into the conductive elements. However, in general, the processes of ion and water absorption by roots (or any tissue) are quite separate and independent.

The water, or "sap," moving from the root to the leaves, then, contains a selection of nutrient ions. The amounts and kinds of ions it contains depend on a number of factors. Within the limits of the selective control exerted by the root cells (to be discussed later), the concentration of any ion in the sap is a function of the concentration in the soil. In some obscure fashion the "needs" of the shoot can be reflected--if the shoot contains ample phosphate, less will be secreted in the sap. Time of day is important, the greatest ion transfer to the sap occuring in the daylight hours. Secretion is increased as increasing amounts of sugar and growth substance move down into the roots from the leaves.

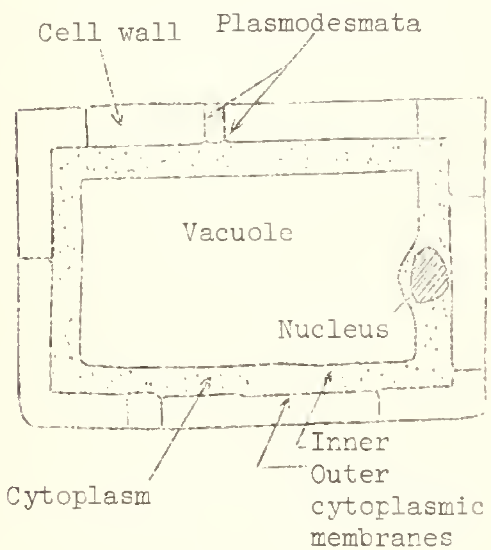
As the sap moves upwards, the cells of the stem and leaves absorb ions from it. This process does not differ from that by which the epidermal root cells accumulated ions from the soil water. So far as is known, the physiology of ion absorption is the same in all cells of a plant, whether the ions are obtained from the soil solution, the xylem sap, or an adjacent cell. The cells of the roots are especially efficient in absorption only because they are organized into a tissue that transports ions away about as fast as they are absorbed.

Although the ubiquity of the ion absorption process enables all cells to accumulate the nutrients essential for

growth, not all cells gain the same amount of ions. The young, rapidly respiring, rapidly growing cells always contain the highest concentrations. When a plant is deficient in nutrients, these young cells will accumulate ions at the expense of the more mature cells. Usually as cells age, they lose the capacity to retain ions, and the nutrients are made available to other, more active cells. Some ions, however, such as calcium and iron, become so firmly fixed in the cell that they cannot be redistributed. These are the "nonmobile" minerals.

The Cell as the Unit of Ion Absorption

Figure 1, in which a plant cell is diagrammed, will help you to understand the physiology of ion absorption.



The cell wall is a strong, somewhat elastic layer of cellulose and pectin made up of innumerable submicroscopic threads, or "micelles." The space between the micelles is filled with water, through which nutrient ions can diffuse readily. In addition, the wall is pierced by tiny pores through which the cytoplasm of one cell is bridged to that of neighboring cells, forming the plasmodesmata. The micelles, as negatively charged colloids, have the capacity to attract and adsorb small amounts of positively charged cations, such as potassium, magnesium, and calcium.

Underneath the cell wall lies a thin layer of cytoplasm. The cytoplasm is the active or "living" portion of the cell. In a healthy cell it is always flowing and streaming. It is composed primarily of complex proteins, which enzymatically carry out the respiratory work of oxidizing sugars to get usable energy and then use this energy to perform all the intricate syntheses and operations of cellular reproduction and growth. One of the important energy-requiring operations is the accumulation (or exclusion) of ions.

The site of ion absorption is probably at one or both of the cytoplasmic membranes. These membranes exist as a sort of fat-protein surface film bounding the cytoplasmic surface. The membranes freely permit the diffusion of water, but sharply restrict the inward and outward movement of solutes in the water, particularly charged solutes, such as nutrient ions.

The proteinaceous compounds of the cytoplasm appear to be largely negatively charged and, like the colloids of the cell wall, can absorb cations. A smaller amount of negative sites for anion adsorption probably exists.

The vacuole is the storehouse of the cell. A good deal of the nutrient ions accumulated by the cell are to be found in the cell sap, along with organic substances like sugar. The inner membrane keeps the solutes from diffusing out of the cell at any appreciable rate. The cytoplasm appears to be able to withdraw substances from the vacuole as needed.

The Physiology of Ion Absorption

A great deal of experimental work has been done on ion absorption, but the mechanism of uptake is still not clear.

This explanation of the process will follow the viewpoint of the widely accepted "carrier" hypothesis, which is supported by most observations.

The first step is the adsorption of ions to the colloids of cell wall and cytoplasm. This process is most apparent with the positively charged cations, as the plant colloids are predominated by negative charges. A very small amount of anions are also adsorbed, however. The adsorption is really an exchange, entirely analagous to the cation exchange exhibited by soil colloids. Cations, such as H^+, occupying sites on the plant colloids exchange places with cations in the soil solution. The exchange apparently takes place deep into the tissue, and sometimes an hour must elapse before exchange equilibrium is reached in a root.

It is not known just which colloids of the cell wall or cytoplasm are predominantly concerned in the exchange. Only colloids of the wall and outer cytoplasmic membrane appear to be readily accessible for exchange, since ion penetration into the cytoplasm should be limited by the outer membrane. However, the outer membrane may not be a fixed structure, but only a limiting layer that is constantly renewed by the continual movement and flux of the cytoplasm. In this case exchange equilibria would be attained by the soil and the entire cytoplasm.

The second phase of ion absorption is transfer of some part of the adsorbed ions throughout the cytoplasm and into the cell sap. This transfer process cannot take place without metabolic energy. The sap concentration of such an ion as potassium may be one hundredfold that of the soil solution. Such a difference in concentration can be attained only by the use of energy in ion-transport work. It has been abundantly proved that when root respiration is limited by reason of low temperature, poor soil aeration, or low sugar supply from the leaves, ion absorption goes on at very slow rates. There is no doubt that respiration furnishes the energy for absorption.

According to the "carrier" hypothesis, the cytoplasm contains certain "carriers" that adsorb ions at the outer membrane and are responsible for transporting ions to the vacuole. These carriers are presumably proteinaceous and can change from a "carrying" to a "noncarrying" condition by using energy. The carrier is visualized as binding an ion at the outer membrane while in the carrying state. The streaming of the cytoplasm (another energy-requiring process) transports the ion-laden carriers throughout the cytoplasm.

The plasmodesmata connect the cytoplasm of adjacent cells, and there is some evidence that ions are transported from cell to cell directly through these cytoplasmic bridges. Eventually the carrier will come into contact with the inner membrane, where some energy-requiring chemical reaction converts it to a noncarrying condition. The bound ion is thereby released into the vacuole. The carrier is eventually returned by streaming to the outer membrane, being reconverted to the carrying condition someplace on the return journey or perhaps at the outer membrane itself.

There is evidence that different kinds of ions have different carriers, or at least different sites on the same carrier. Plant cells exhibit a good deal of ion selectivity that may be explained by the selective binding of ions by the carriers. Cells are not able to absolutely exclude unneeded ions, however, and even metabolically useless ions, such as gold, can be taken up. It appears that the binding sites of the

carriers will be preferentially filled by nutritive ions, but some small fraction of sites can be occupied by other ions, particularly when the concentration of nutritive ions in the soil is low.

Plant cells not only accumulate large amounts of needed ions from low soil concentrations, but also work to exclude unneeded ions. For example, soils are sometimes high in sodium and low in potassium. A healthy cell will use energy to maintain low sodium, high potassium concentrations. How they do it is not known, but it can be shown indirectly that the carriers bind potassium in preference to the chemically similar sodium ions.

The total amount of any ion that is bound to the carriers at any one time is related to the concentration of that ion in the soil. The relation is not a simple one. When soil concentrations of an ion become lower and lower, the amount of that ion absorbed by the cells also falls off, but not to the same degree. Percentagewise, roots are more efficient in absorbing ions from low soil concentrations than from high ones. This circumstance is a fortunate one because it allows plants to continue to grow with seasonally fluctuating amounts of available nutrients. However, the rate of crop plant growth always diminishes when soil nutrient concentrations decline.

Some investigators have compared the ion absorption process to a conveyor belt. The amount of material carried by the belt will depend on the speed at which the belt runs and on the rate at which the belt is loaded. The cytoplasmic carriers are likened to the belt. The speed at which they complete a round trip between the outer and inner membranes depends on the respiration rate. The load the carriers transport, on the other hand, depends on the external concentration of ions. The carriers are maximally "loaded" only when external ion concentrations are high.

Different species of plants exhibit different efficiencies in absorbing ions. Some weeds are quite well adapted to scavenging ions from a poor soil. Grasses, in general, are much more efficient in absorbing potassium than are the legumes, and this can be a factor in the gradual elimination of legumes from pastures.

From a practical viewpoint, the ion absorption process is most efficient when these requirements are met:

1. The soil has high concentrations of nutrient ions.

2. The soil is well aerated, allowing oxygen to diffuse readily into the soil and CO_2 to diffuse out.

3. The soil is sufficiently moist to permit ions in solution to contact large areas of root. The entire movement of ions into and through the root is accomplished in an aqueous medium. If water is limiting, the medium for transport is limiting.

4. The leaves are exposed to adequate light. The roots receive their energy-giving sugars from the photosynthesizing green leaves. When plants are shaded (a result of too-heavy planting rates), the root sugar content drops, and there is a consequent decrease in growth and ion absorption.

J. B. Hanson
2-28-55

AGRONOMY FACTS

TRANSMISSION OF PLANT DISEASES BY INSECTS

Nearly everyone who has ever grown plants has either seen or experienced the direct injury inflicted upon plants by insects. On the other hand, only a few people, farmers included, are aware of the indirect damage that some insects cause by aiding in the spread and development of plant diseases. This unawareness is probably due to failure to associate earlier insect infestations with a disease that may require from several days to several weeks to appear. Sometimes nearly all insects have disappeared by the time the first symptoms of the disease can be seen.

Insects may carry such disease-producing entities as bacteria, fungi, and viruses. Fortunately, of all the thousands of species of insects that exist, only a relatively few species function as vectors or carriers of disease. In addition, the insects that have been found to act as vectors seem to be rather specific, and only a few species transmit more than one disease.

The losses from plant disease spread by insects vary greatly. Stated simply, the amount of loss will depend upon: large populations of susceptible plants, presence of the organism causing the disease and of active vectors carrying the organism, and environmental conditions favoring infection and disease development. Fortunately, all of these conditions do not usually occur at the same time, and losses for different diseases therefore vary greatly from year to year and from locality to locality.

Bacterial diseases. The bacterial wilt of corn is spread primarily by two species of flea beetles. The bacteria survive during the winter in the bodies of adult beetles and are introduced into wounds when the insects feed on the leaves. Obviously, the logical method of control would be to kill the beetles, and certain insecticides are now being used with a considerable degree of success. Theoretically, an efficient insecticide would have to be applied only in the years that are favorable for the winter survival of the beetles (i.e., a mild winter). The recent development of wilt-resistant sweet corn hybrids has also helped to reduce the loss from this disease.

Fungus diseases. The Dutch elm disease is an example of a fungus disease that is spread by insects. If it were not for two species of bark beetles, the disease would spread very slowly, since the fungus has no other effective way of reaching elms except through naturally occurring root grafts. Not only do the beetles carry the fungus to healthy trees, but they also provide the necessary wounds through which the fungus may infect the tree.

Virus diseases. Many plant viruses are spread by insects--most frequently by a species of aphid or leafhopper. Both types of insects possess sucking mouth parts. Injection of virus by the vector occurs irregularly during feeding. In order to transmit the virus to healthy plants, the insect must first acquire the virus by feeding on diseased plants. In general, transmission may be divided into two types: one in which the virus is rapidly "lost" by the insect vector if it does not have access to a fresh source of virus, and the other in which the virus is retained by the insect for long periods--often for the remainder of its life. Other things being equal, it is obvious that greater spread would occur with this latter type.

For an insect-transmitted virus to cause serious losses in an annual crop raised from seed, the virus must spread rapidly. This can occur only if the crop is easily infected, the source of virus is readily available, and the vector is very numerous and active.

Control. Control practices for insect-transmitted diseases are essentially the same as those employed for other plant diseases, i.e.: (1) use of varieties that either do not appeal to the vector or are resistant to the disease; (2) employment of cultural practices, such as altering the date of planting or rate of seeding, digging up diseased plants, etc.; and (3) use of chemicals to kill the vector. The particular control practice to use will vary with the disease.

R. M. Takeshita
5-9-55

PASTURE MANAGEMENT

Good pasture management is essential in getting continuous, maximum yields of palatable and nutritious forage throughout as long a season as possible. Good pasture management includes these fundamentals:

1. A good fertility program

2. A full-season pasture plan

3. Rotational grazing of tall-growing grasses and legumes

4. Periodic clipping

5. A convenient layout

Good fertility program. To keep good legume-grass seedings productive, top-dressings of potash and phosphorus carriers, in amounts based on soil tests, should be made once a year or at least every two years. Use of nitrogen fertilizer on a grass-legume mixture will tend to stimulate growth of the grass. Nitrogen fertilizers are often used on pure grass pastures or on older grass-legume mixtures where the legumes have been eliminated.

Full season pasture plan. To get high production throughout a long grazing season, it is usually necessary to provide for:

a. Early spring grazing through the use of a small grain, such as rye, or a nitrogen-top-dressed permanent pasture. Nitrogen top-dressing on permanent pastures in late February and early March usually brings them into production about 10 days to two weeks earlier than nontreated pasture.

b. Spring and early summer grazing in the form of a renovated permanent pasture.1/

c. A productive rotation pasture with mixtures of tall-growing grasses and legumes, such as smooth bromegrass, alfalfa, and Ladino clover for midsummer and early fall grazing.

d. Emergency pastures, such as Sudan grass and Korean lespedeza, for use during mid- or late summer dry periods. Many of these emergency pastures are discussed in detail in Circular 726, "Crops for Emergency Plantings," by W. O. Scott.

Sound pasture management provides for a reserve of forage at all times in the form of unused pasturage, grass silage, or hay to bridge such emergencies as a severe winter, summer drouth, or partial crop failure. The tall-growing pasture plants, such as smooth bromegrass, orchard grass, tall fescue, alfalfa, Ladino clover, and red clover, as well as the liberally fertilized permanent pastures, are especially productive during May and June. Ensiling surplus herbage during these months is advantageous for the following reasons:

a. It is usually difficult to make hay during this period because of high moisture.

b. April, May, and June are the months when bloat is worst, and ensiling forage from mixtures containing a high percentage of Ladino will provide bloat-free feed.

c. Early production of many of our tall-growing pasture plants is usually

1/ See University of Illinois Agricultural Experiment Station Circular 703, "Five Steps in Pasture Improvement," by E. D. Walker and J. C. Hackleman.

more stemmy and coarse than later production. This stemminess is less undesirable in grass silage than in either hay or pasture.

Rotational grazing of tall-growing grasses and legumes. Usually three or more fields containing different mixtures are needed to provide uniform, palatable, continuous grazing. Tall-growing pasture mixtures containing smooth bromegrass, Ladino clover, and alfalfa will not produce maximum yields unless they are rotationally grazed. They should therefore not be grazed continuously, but should be divided into two or three fields so that one can be grazed while the others have time to recover.

The value of rotational grazing on unimproved permanent pastures is questionable. Most tests show that there is usually not enough increase in production or carrying capacity to justify the expense of providing the additional fencing, water, and shade for the additional fields.

Periodic clipping. When animals are changed from one pasture to another, mowing the ungrazed fields will improve the growth and quality of future herbage. Clipping will also help to eliminate weeds that might crowd out the legumes and grasses.

Convenient layout. If there is a choice of location, pastures should be located near the barn, shade, and water. It takes energy for animals to travel long distances to graze and get water. This same energy might better be converted to beef, milk, or mutton than wasted on long walks.

A. W. Burger
11-8-54

CROPS

COLD AND WINTER INJURY OF FORAGE LEGUMES

F-13

There are at least four distinct types of cold or winter injury that may occur on forage legumes:

1. Frost injury to the growing plant in the spring or early fall.
2. Heaving caused by alternate freezing and thawing.
3. Damage to the root and crown from low temperatures.
4. Ice-sheet injury.

Frost injury is the least important of the four types. Damage is generally slight, and the plants almost always recover. When temperatures drop below the freezing point in the spring, after plants have begun to grow, the tops may be killed and the dead leaves become light tan.

Water in plants can sometimes remain unfrozen (supercooled) when temperatures are below the freezing point. If such plants are suddenly jarred, ice crystals form and the top growth is killed. If an animal, walks through a field of alfalfa or other crop that is supercooled below the freezing point, every plant that is disturbed will freeze. The result is the peculiar brown streaks that are sometimes seen in fields of forage crops in the spring.

Heaving due to alternate freezing and thawing often severely injures stands of forage legumes. Legumes with an unbranched taproot, such as alfalfa, are most apt to heave, while those having a more branched and fibrous root system, such as red clover, are less likely to heave. Heaving occurs most often on wet poorly drained land.

Damage from low temperatures occurs when unadapted varieties are used. In Illinois one should expect stands of southwestern alfalfas to be killed by low temperatures during an average winter. In unusually cold winters, even adapted varieties may be injured or killed. Plants weakened by low temperatures are also most susceptible to such diseases as bacterial wilt and root rots.

Too frequent cutting, continuous pasturing, or cutting of a hay crop during the critical period from September 1 to October 15 tends to weaken the stand and make it more susceptible to injury from extreme cold.

Ice-sheets cause the most serious injury. Sleet storms or freezing rain may cause ice to form over wide areas, and often the result is complete losses of stands. Ice-sheets can also form in poorly drained areas where water from rain or melting snow accumulates. The varieties that are most resistant to extreme cold are also most resistant to ice-sheet injury. Alfalfa varieties tested for ice-sheet resistance at the University of Wisconsin were rated in this order, from most resistant to most susceptible: Rhizoma, Ladak, Grimm, Ranger, Buffalo, Kansas Common, Oklahoma Common, and New Mexico Common. In comparative tests, red clover was much more susceptible to ice-sheet injury than either alfalfa or sweet clover. In other experiments, Ladino clover was more susceptible to injury than white clover.

J. W. Gerdemann
12-13-54

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

F-14

SEEDING FORAGE GRASSES AND LEGUMES

Importance of planting depth in relation to soil moisture. A seed that has begun to germinate will die if it is allowed to dry out. However, the seeds of most forage plants are so small that they should not be planted more than 1/2 inch deep. If they are planted deeper, many of them will die from exhaustion of their food supply before they emerge.

The problem in establishing forage crops is to plant the seed deep enough to keep it from drying out and yet not so deep that the seedling cannot emerge. In general, as the season progresses from late winter through spring into summer, more of the upper soil layer dries out and some precautions have to be taken to protect the seed.

Surface-seeding legumes in late winter and early spring. It is common practice to seed red clover on winter wheat and the other winter cereals in late winter and early spring when it is still freezing at night and thawing in the daytime. The freezing and thawing works the seed into the soil. At this time of year the soil surface does not dry out during the day, and it is possible for the seedlings to become established even though they have little or no soil covering.

The main hazard to seeding at this time of year is that killing frosts frequently occur after the seeds have begun to germinate. However, a certain proportion of them usually do not begin to germinate immediately because their seed coats are impervious to water until after they have been in the soil for a certain period or have been exposed to frost. Therefore, when the first lot of seedlings are killed back by a frost, there are usually enough of these so-called hard seeds to make a satisfactory stand.

The fact should be recognized that conditions are not so ideal when seedings are made in the spring on winter cereals as when a seedbed is prepared and the forage seedlings start off at the same time as the companion crop or, better yet, without a companion crop.

The seed may be broadcast in any one of several ways. The "windmill"-type seeder is most often used. This type is available in several forms, from hand-operated types that are carried by the operator to those that are mounted on a tractor. Some types of fertilizer spreaders can be calibrated for seeding. With any of these types it is possible to seed when the soil is too wet for drilling.

Spring seeding with a small-grain companion crop. In the northern half of Illinois, most forage crop seedings are made in the spring with a companion crop of oats. The forage seeding is made through a grass-seed attachment at the same time as the small grain is drilled. On many drills, tubes carry the seed from the forage seedbox into the small grain tubes, and the forage seeds are planted at the same depth as the small grain--many times deeper than it should be planted.

In such cases the tubes carrying the forage seed should be pulled out of the small-grain tubes and allowed to swing free. The forage seed will then be broadcast on the surface of the prepared seedbed, which is somewhat rough. It will settle into the irregularities of the soil surface and be covered. The soil thrown up by the discs in sowing the cereal will also cover some of the seed—much of it too deeply.

The seeding of forages can be improved by using a flexible tubing, such as a

garden hose, to carry the seed from the grass-seed box to about 14 inches back of the discs, where it is allowed to drop about a foot. This distance behind the disc is suggested so that the soil disturbed by the disc will be allowed to settle back into place before the seed drops on it. Conversion units are commercially available for adapting the standard grain drills for seeding in this way. Many farmers, however, adapt their drills with materials thay have on hand.

If no fertilizer is being applied, the seed should be allowed to scatter. However if a starter fertilizer with phosphorus and potassium is being put down with the small grain, the forage seed should be confined to a narrow strip right over the fertilizer.

If moisture conditions are favorable, there is no need to cover the seed when it is dropped on the surface in the drilling operation. If, however, the seeding is done when the soil surface is likely to dry out, the field should be rolled immediately after seeding.

Late spring, early and late summer seedings. Seedings after May 1 are usually made without a companion crop. They should be rolled because moisture is likely to be critical in hot weather. It is desirable to drill the seed as shallow as possible and then roll the seedbed. Legume seedings may be successful throughout the summer, but grass seedings are most successful when made in early spring or in late summer or fall. Not many seedings are made in July because of expected high temperatures, but August and early September seedings are common and are usually successful in the southern half of the state.

The cultipacker-type seeder has many features that make it desirable for planting forages. The drill consists of two cultipacker-type rollers. One roller runs behind the other and is lined up in such a way that it splits the ridges made by the first section. The seedbox is set between the rollers, and the seed drops down between them. It falls into the troughs between the ridges made by the first section and is covered when the second section splits the ridge. Thus it is pressed firmly into the soil at a depth of about 1/2 inch. With this type of seeder the seeding rate can be cut from one-fourth to one-half below the rates used with conventional methods.

Spring versus late summer seedings. In general, spring seedings favor the legumes, and late summer and fall seedings favor the grasses. The legumes can compete better than the grasses with the summer annual weeds that flourish during hot summer weather. In the fall, however, the grasses will continue to grow longer than the legumes, and there is not much competition from weeds at this time of year. Therefore, the later in the season a grass-legume mixture seeding is planted, the more prominent will be the grass in the mixture the following year.

J. A. Jackobs
3-21-55

SORGHUMS IN ILLINOIS

There are four types of sorghums--forage, grain, grass, and broomcorn. All four types can be grown successfully in Illinois. Sudan, which is a grass type, has long been recognized to be the best supplementary summer pasture available to Illinois farmers. Broomcorn seed and brush are important crops in certain communities of east-central Illinois, and the grain and forage types of sorghum have been used to some extent in the state for many years.

Unless rainfall is below normal, sorghum can be considered less well adapted to the production of either grain or forage than is corn. But there is a place for sorghum, especially the forage types.

Forage Sorghum - The forage types of sorghum grow tall and produce heavy yields of forage or silage but relatively low yields of grain. The stalks, which are sweet and juicy, are resistant or tolerant to chinch bug injury.

The forage types can be used for silage throughout the state. In years when rainfall is below normal, they will produce more silage and total digestible nutrients per acre than corn because they are resistant to drouth. When rainfall is normal or above, they will usually produce more tons of silage than corn, but corn may produce more total digestible nutrients per acre.

A few acres of forage sorghum for silage may be good insurance against dry weather on any livestock farm.

The later maturing varieties usually grow taller and produce more silage than do the earlier, short-growing varieties. Selection of the right variety to fit the growing season is important. If the variety is too early, it will not produce maximum yields. If too late, it may not get dry enough before a killing frost to make good silage.

The forage types can be cut and shocked for dry feed or used for silage. They should not be cut for silage or fodder until the grain is in the stiff-dough state. If they are cut earlier, there is real damage that the silage may sour. Because the plant remains green, sorghum will retain optimum moisture for ensiling over a longer period than will corn. Corn is in the proper stage for ensiling for only 7 to 10 days. Sorghums remain in the proper stage for 20 to 30 days.

All sorghum varieties tend to lodge after they are ripe. Consequently it is important to harvest the crop as soon as it is ready.

Atlas is one of the most popular forage varieties. It stands well, yields well, and matures in about 120 days. It can be used throughout the southern half of the state but is too late for northern Illinois. Early Sumac or Rox is better adapted to the northern section. Following are a few forage varieties and their relative maturity dates:

Kansas Orange	120-130	days
Atlas	120	"
Leoti Red	110	"
Axtell	105-110	"
Norkan	105-110	"
Ellis	105-110	"
Rox	105-110	"
Early Sumac	100-105	"
Fremont	95-100	"

Grain sorghum is not generally recommended for Illinois. This is not because it will not produce grain, but because there are some hazards associated with growing and storing the crop under the more humid conditions of Illinois.

Grain sorghums are relatively short growing and usually have dry stalks that are not sweet. They are low producers of forage and relatively high producers of grain. As a group, they vary tremendously in their reaction to chinch bug damage, but they can generally be classed as susceptible, particularly the shorter combine types. The kafirs, which are too tall to be combined, are resistant to chinch bugs, but there is very little interest in these taller growing grain types. For this reason they will not be included here.

The hazards of producing grain sorghums include damage by chinch bugs, aphids, and birds. But the main problem is getting the grain dry enough to store successfully. The fact that the seed is relatively soft and is produced in a compact head makes it hard to get it dry enough in the field to store well. The plant stays green until it is killed by cutting or by frost, and the grain tends to dry very slowly.

The grain can be combined as soon as it is mature even though the plant is still green, but it must be artificially dried if it is to be stored successfully. Twelve percent moisture is the maximum for safe storage. Some of the combine types of grain sorghums and their respective maturity dates are:

Redlan	115-120 days
Wheatland	105-115 "
Midland	100-110 "
Martin	100-105 "
Early Kalo	95-100 "
Coes	90-100 "
Colby	90 "
Norghum	85- 90 "
Reliance	85- 90 "

Cultural Practices - The sorghums are warm-weather crops that cannot be planted until the soil warms up in the spring (the last of May or the first of June). The seed should be treated with Ceresan M, Arasan, or Spergon before planting. The seedbed should be prepared similar to that for corn.

With minor changes, such as planting plates, the planting equipment is the same as that for corn. For forage sorghums the planting rate is 5 to 8 pounds per acre in 36- to 40-inch rows; for grain sorghums, 3 to 5 pounds per acre. The crop is cultivated with the same equipment used for corn.

Experiments in the western states indicate that yields of grain sorghums can be increased by planting in narrower rows. But because the crop must be cultivated to control weeds, the rows must be wide enough for that purpose.

The western states report that 2,4-D can be used to control weeds in sorghums; the rate of application is similar to that for corn. The crop is apparently most tolerant to 2,4-D in the early stages of growth (when less than 18 inches tall).

W. O. Scott
3-28-55

THE IDENTIFICATION OF SOME COMMON GRASSES BY THEIR VEGETATIVE CHARACTERS

It is often necessary to identify certain grasses before they have flowered or after they have been closely grazed. In such cases, they must be identified by the vegetative characters of the basal and root portions of the plant. The following definitions and distinguishing features should be helpful in identifying some common grasses by their vegetative characters.

Definitions of Terms Used in Vegetative Morphology

Auricle - claw-like appendage projecting from the collar of the leaf.

Blade - flat, expanded part of a leaf.

Collar - narrow band marking the place where the blade and sheath join.

Glabrous - devoid of hairs.

Ligule - appendage around the culm at the juncture of the sheath and the blade of a leaf.

Rhizome (root stock) - an underground stem which can produce roots and shoots at the nodes.

Scabrous - rough to the touch.

Sheath - lower part of a leaf which envelops the stem.

Stolon - creeping above-ground stem, leaf bearing and frequently rooting at the joints.

Vernation - arrangement of leaves in the bud.

The following information may be used to help in the recognition and separation of the grasses, sedges, and rushes:

Character	Grasses	Sedges	Rushes
Leaf arrangement	Two-ranked	Three-ranked	Three-ranked
Culm cross-section	Cylindrical or flattened	Usually three-sided	Cylindrical
Nodes	Distinct	Indistinct	Indistinct
Collar	Distinct	Indistinct	Indistinct
Auricles	Present or absent	Absent	Absent
Ligules	Usually present	Usually absent	Usually absent
Leaf margins	Smooth, rough or hairy	Usually rough	Smooth

Distinguishing Features Between Grass Species and Grass-Like Plants

There are a number of plants in pastures and meadows that might be confused with true grasses (Gramineae). These belong to two plant families, sedges (Cyperaceae) and rushes (Juneaceae). The true grasses have the following characteristics.

In using the following key to the common grasses, it should be understood that it involves a process of elimination of one of two possible places of fit for a particular grass specimen, e.g., the first two possible places of fit are either 1a or 1b. If the grass specimen fits the characterization of 1a, the next two places of fit are 2a and 2b under 1a. This process of elimination is continued until the characterization fits the grass specimen in question. This key represents only a small segment of the more than 1500 species found in the U.S. alone.

GRASSES*

1a. One half or more of the ligule length consisting of hairs (do not confuse long and acuminate teeth with hairs)

2a. Definite rhizomes present (the rhizomes may be left in the ground in pulling up the culms)

3a. Long hairs on outside of collar, both rhizomes and stolons ------------------------1. Cynodon dactylon, Bermuda grass

3b. No long hairs on outside of collar (may be on inside or margin); sod formers with definite long rhizomes--no stolons

4a. Long hairs (at least twice as long as the ligule hairs) present on base of blade; margins of leaf blades weakly scabrous -----------------------2. Panicum virgatum, switch grass

4b. No long hairs present on collar or base of blades; margins of leaf blades strongly scabrous. ------------------------3. Spartina pectinata, slough grass

2b. No rhizomes present; plant low, producing stolons and forming a sod; leaves very short and borne in tufts at the nodes of the stolons--------------4. Buchloe dactyloides, buffalo grass

1b. Hairs usually lacking from the ligule margin or when present constituting less than one-half the total length

2a. Definite auricles present

3a. Definite rhizomes present; leaf blades narrow, blue-green or glaucous----------------5. Agropyron smithii, western wheat grass

3b. No rhizomes present

4a. Leaves usually more than 8 mm. wide, nerves conspicuous, especially on upper surface - not glossy -----------------------6. Elymus canadensis, Canada wild rye

4b. Leaves usually less than 6-7 mm. wide, nerves not conspicuous below, blade glossy below--Festuca elatior, meadow fescue

2b. No auricles present

* This key adapted from "Key to Some Colorado Grasses in Vegetative Condition" by H. D. Harrington and L. W. Durrell, Colorado Agricultural Experiment Station Technical Bulletin 33, June 1944.

3a. Sheaths closed almost their entire length (may be split on old sheaths)

4a. Definite rhizomes present, leaves over 6 mm. wide --------------------7. Bromus inermis, smooth bromegrass

4b. No rhizomes present; vernation folded or clasping, the edges of the leaf in the bud not overlapping; sheaths usually glabrous and somewhat flattened in section --------------------8. Dactylis glomerata, orchard grass

3b. Sheaths open to near base

4a. Base of culm bulbous, enlarged----9. Phleum pratense, timothy

4b. Base of culm not bulbous

5a. Definite rhizomes present

6a. Leaf blades over 10 mm. wide----10. Phalaris arundinacea, reed canary grass

6b. Leaf blades less than 10 mm. wide

7a. Vernation folded, the edges of leaf blade in bud not overlapping

8a. Leaves V shaped in cross section and boat shaped near end. Rhizomes long------------11. Poa pratensis, Kentucky bluegrass

8b. Leaves not boat shaped near end; rhizomes, when present, very short---------------12. Andropogon scoparius, little bluestem

7b. Vernation rolled, the edges of the leaf blade in the bud definitely overlapping------13. Agrostis alba, redtop

5b. Definite rhizomes not present

6a. Annual grasses. Sheaths definitely flattened; vernation folded, ligules rarely over 1 mm. long -----------------------14. Eleusine indica, goose grass

6b. Perennial grasses (in vegetative condition an annual would be a seedling; a perennial would have an enlarged root or culm base from which the new growth develops)

7a. Vernation folded or clasping; ligules less than 2 mm. long -----------------------15. Andropogon scoparius, little bluestem

7b. Vernation rolled, margins of sheaths not ciliate, ligules less than 2 mm. long----16. Arrhenatherum elatius, tall meadow oat grass

A. W. Burger
4-25-55

DO VARIETIES OF SMALL-GRAINED CEREALS "RUN OUT"?

Some growers of small grains believe that after a variety has been grown for a period of years it goes through some kind of change that causes it to yield less than when it was first distributed. This process is called "running out." The term is not usually applied to reduction of yield by disease, lodging, or other obvious cause. It is used when yield goes down but the grower cannot put his finger on the exact cause.

This idea that varieties "run out" persists among certain growers, and it is difficult if not impossible to explain away. If disease, lodging, or some other easily detectible cause is not responsible for the decrease in yield, what is?

Lower yields may be due to changes in hereditary makeup of a variety. Or the soil on which a crop is grown may not be so productive as when it was first grown. Or climatic conditions may have become less favorable for growth of the variety.

Hereditary changes great enough to reduce yields to any great extent are not common. Results of several tests with mixtures of wheat varieties and hybrid populations of barley show that natural selection soon eliminates the unadapted types. In a short time the population consists of only one or a few adapted types. With the elimination of the unadapted types, yield increases until it reaches a level that is affected only by environmental differences. If the environment is favorable, we should expect deleterious changes in hereditary makeup to be eliminated and yield to be maintained or even increased.

If it is true that varieties of small grain "run out," then yield should decline when a variety is grown for a long time at one location. But our results in tests at the Agronomy South Farm do not show such declines.

At the South Farm several varieties of oats have been grown for a long time on the same series of plots. Sixty Day has been grown since 1905. Average yields for this variety, by ten-year periods since 1905, have been 57.95, 54.12, 64.05, 62.30, and 57.80 bushels an acre. The average for the entire period is 59.6 bushels. Average yield was lowest in the second ten-year period, highest in the third, and about the same in the first and last periods. These data do not provide any evidence for "running out."

Growing conditions change from year to year and from place to place. Growers tend to use their most fertile soil for a new variety because they want a maximum increase of a limited amount of seed. Later, when the variety takes its place in the rotation, it may be grown on less fertile soil, and consequently the yield may go down.

It is also hard to remember what growing conditions are like over a long period. We tend to forget the changes from season to season. If a variety is introduced at a particularly favorable period and conditions later become unfavorable, we usually blame the variety.

Average yields of all oat varieties grown in the variety trials at Urbana also disprove the theory of "running out." Results of four common varieties grown in tests from 1945 to 1954 are given in the table on the back.

(Continued on other side)

Comparison of Yields of Oat Varieties Grown at Urbana, Illinois, 1945 to 1954

Variety	1946	1947	1948	1949	1950	1951	1952	1953	1954
Clinton	72	93	63	44	49	57	62	54	68
Columbia	71	88	57	38	42	53	55	58	70
Marion	70	88	71	43	48	55	64	61	63
Sixty Day	68	83	59	39	45	55	59	51	59
Average, all varieties	71	81	66	44	46	55	61	58	67

The average yield for all varieties shows the trend. Yield was high at the beginning of the period, declined toward the middle, and increased at the end. Each variety followed this same trend. Clinton was introduced in Illinois in 1946, when oat yields were high. Growing conditions for oats have not been so good at Urbana since the major increase in Clinton in 1946 and 1947. If we were to combine this seasonal change with the effect of stem and leaf rust on yield, we might conclude that Clinton was "running out," when actually it has only been responding to a change in growing conditions.

From these data we can draw the conclusion that changes in the yield of small grain varieties can be caused by soil variations, climatic changes, incidence of disease, and other causes. Yield decline is so rarely, if ever, due to hereditary causes that it need not be considered in connection with the idea of "running out."

O. T. Bonnett
11-15-54

WINTER OATS IN SOUTHERN ILLINOIS

Questions have arisen in recent years about the possibility of growing winter oats on some of the acres taken out of wheat production by acreage allotments in southern Illinois. This fact sheet is being prepared to answer some of these questions and to bring farmers up to date on some of the most recent information on growing winter oats in southern Illinois. Agronomy Mimeograph AG1617 gives more detailed information on this subject.

Winter oats have several important advantages over spring oats in southern Illinois. When winter oats survive the winter, they can be expected to give higher yields of better quality grain than the spring types. Since winter oats mature several weeks earlier than spring oats, they usually escape the more important diseases and the dry, hot periods that often come between the time of heading and maturing of spring oats. Winter oats can also serve as a source of late fall and early spring pasture, as an erosion-control measure, and as a companion crop for legumes and grasses.

Since winter oats are more susceptible to winter injury than winter rye, wheat or barley, their production is restricted to southern Illinois. In some years they will be damaged by cold even in the extreme southern section of the state. But they can usually be grown successfully south of U.S. Route 50, which crosses the state from Vincennes, Indiana, to St. Louis, Missouri, if one of the more winter-hardy varieties is used along with recommended cultural practices. In many years winter oats will survive farther north than Route 50, but production is extremely hazardous north of this line. However, it would be possible to use a spring crop, such as spring oats or soybeans, on fields of winter oats that failed to survive the winter, and in this way the only loss would be the cost of seed, land preparation, and seeding.

Cultural Practices

Early seeding is recommended in order to give the crop a chance to become well established before freezing weather. To obtain best results, seedings should be made in early September. If late fall pasture is desired, seeding should be done in August. Late seedings will be more likely to winterkill than those made in early September. Seedings do not have to be delayed to avoid Hessian fly because winter oats are usually not damaged by this insect.

Seeding with a drill at two to three bushels an acre is a recommended practice. The more winter-tender varieties should be seeded at a higher rate than the hardy varieties.

Winter oats respond readily to fertile soils. Spring applications of nitrogen usually give good results. Since winter oats have a better root system and stronger stems than spring oats, they can handle larger amounts of nitrogen.

Varieties

Winter-hardiness is the most important characteristic to be considered in choosing a winter oat variety for southern Illinois. On the basis of tests at a number of locations in the state, the following varieties are being recommended: Wintok, Fulwin, Dubois, Forkedeer,

and Le Conte. Wintok and Fulwin are the most winter hardy of the recommended varieties. Dubois and Forkedeer are slightly less hardy but have given high yields in most of southern Illinois. Le Conte is the most winter-tender of the recommended varieties and for this reason should be restricted to the extreme southern tip of the state. Le Conte has very stiff straw and gives good yields when it survives the winter.

In summary, it appears that winter oats can be successfully grown in many parts of southern Illinois if winter-hardy varieties are used. Farmers should be encouraged to buy pure seed of a recommended winter-hardy variety before attempting to grow winter oats any place in Illinois. It may be desirable to try them on a limited scale the first year and then, if satisfactory results are obtained, the farmer can save his own seed for future plantings and in this way avoid the cash outlay for planting seed. Information on sources of winter-hardy varieties can be obtained from the county farm advisers, Illinois Crop Improvement Association, or the Agronomy Department of the University of Illinois.

C. M. Brown
5-16-55

FALL NITROGEN APPLICATIONS IN ILLINOIS

Applying nitrogen in the fall helps to distribute the labor load on farms and relieve storage problems of fertilizer companies. In humid regions there is a possibility that a good part of nitrogen applied in the fall may leach out. On the other hand, such applications can be made satisfactorily by giving careful attention to these points:

1. Kind of carrier applied
2. Amount of nitrogen applied per acre
3. Soil temperatures at time of and after application
4. Soil characteristics, particularly subsoil permeability
5. Rainfall and depth to which water percolates
6. Vegetative cover
7. Kind of residues plowed under

Kind of carrier. Soils contain available nitrogen in both nitrate and ammonium nitrogen forms. Nitrate nitrogen is leachable. Ammonium nitrogen is nonleachable and remains so unless microbes convert it to nitrate nitrogen.

Some fertilizers may supply nitrogen in either nitrate or ammonium form or in varying combinations of both. Still others, such as urea and calcium cyanamid, contain neither nitrate nor ammonium nitrogen. But, when soil temperatures and moisture are favorable, microbes convert these materials first to ammonium and then to nitrate nitrogen. The potential loss of fall-applied nitrogen on permeable soils in areas of relatively high rainfall will therefore depend on the carrier. The potential leachability of nitrogen carriers is shown in Table 1.

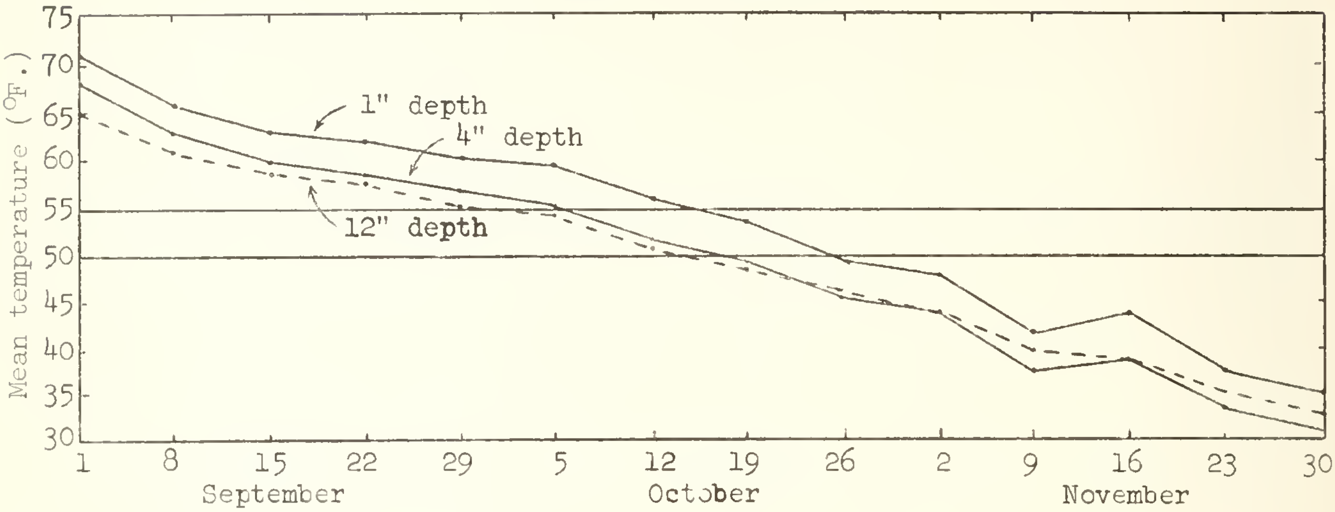
Table 1.-- The Potential Leachability of Nitrogen Carriers Applied on Permeable Well-Drained Soils

Nitrogen carrier	N	Leachable	Nonleachable
	pct.	pct.	pct.
A-N-L	20.5	50	50
Ammonium nitrate	33.5	50	50
Ammonium sulfate	20.5	..	100
Ammonium sulfate-nitrate	26.0	24	76
Ammo-phos (16-20-0)	16.0	..	100
Anhydrous ammonia	82.0	..	100
Calcium cyanamid	20.0	..	100
Cal-Nitro	20.5	50	50
Nitrate of soda	16.0	100	..
Solution 37	37.0	32	68
Uran 32 (Sol. 32)	32.0	24	76
Urea	45.0	..	100

Soil temperatures. The microbial population must be relatively inactive if a soil is to retain fall-applied nonleachable nitrogen. Nitrification, which is a function of certain bacteria, ceases at 32° F. The rate of nitrification is low at temperatures ranging from 50° to 55° F. In Illinois soil temperatures drop below 50° F. rather rapidly in the fall (see Figure 1). Under these conditions nitrification soon ceases. If possible, therefore, nonleachable forms of nitrogen should not be applied until the soil reaches this temperature.

One can wait for nitrification to cease entirely and risk bad weather that may prevent making a fall application of nitrogen. Or one can apply nonleachable nitrogen at slightly higher soil temperatures during favorable weather, knowing

Figure 1.--Soil Temperatures at Urbana, Illinois, at 1-, 4- and 12-Inch Depths (1948-1953 inclusive)*



*Data courtesy State Water Survey, Meteorologic Laboratory, Urbana, Illinois

that some of it may be converted to leachable form. The temperature of 50° to 55° F., therefore, is a compromise.

Table 1 shows average fall soil temperatures at Urbana at depths of 1, 4, and 12 inches. The date on which the soil reaches a temperature of 55° F. will vary from year to year depending on latitude, air temperature, direction of slope, etc. It is therefore best to measure the temperature of the soil before applying nitrogen.

Temperatures decline more slowly at the soil surface than at depths of 4 to 12 inches. In general, the temperature reaches 55° F. at a depth of 1 inch about two weeks later than at 4 to 12 inches. Thus nonleachable nitrogen that is applied to the soil surface, when the soil temperature is 55° F. at the 4-inch depth, will nitrify more rapidly, provided moisture is favorable for microbial growth, than nonleachable nitrogen that is plowed under.

Soil characteristics. Water is the chief means of moving nitrate nitrogen through and out of the soil. Any soil characteristic that impedes or retards the free flow of water through the soil profile therefore reduces drainage losses of nitrate nitrogen.

On soils having tight clay subsoils with very low permeability, nitrogen can be applied in the fall, regardless of type of carrier or soil temperature, without serious loss through drainage. Cisne and related soil types in southern Illinois and Clarence and related types in east-central Illinois are good examples. Applying nitrogen for wheat on Cisne soils in the fall would make it unnecessary to apply it in the spring when the soil is excessively wet and soft.

On medium-heavy to heavy-textured soils with permeable subsoils having good internal drainage, however, only nonleachable carriers should be applied in the fall when soil temperatures are below 55° F.

Rainfall. Fall and winter rainfall in Illinois is sufficient, as a rule, to more than replace subsoil moisture reserves depleted during the growing season. On permeable soils the excess moisture either drains away in tiles or is added to ground water reserves. It is this excess moisture that contributes to nitrate drainage losses.

The amount of rain needed to initiate tile flow will vary with soil texture. An equal amount of rainfall will penetrate deeper in soils with sandy profiles than in soils with heavy clay subsoils. We can therefore expect more nitrate loss through leaching on sandy soils than on the heavier soils. On sandy soils nonleachable nitrogen can be applied in the fall for winter grains. For corn, however, sidedressing is preferable to plowing under either fall or early spring applications, because spring-formed nitrates may leach considerably before the corn roots develop.

In the normally drier areas of the Midwest, fall and winter rains seldom soak deeper than 4 feet into the soil. Thus no leaching beyond root penetration occurs and even nitrate-containing carriers may be fall-applied. For the past two winters the subsoil has been dry in certain parts of Illinois. This dryness may account for the reported success of fall applications of nitrate-containing carriers. The fact that no water has discharged through tiles for many months is not normal. Nitrogen applications made in the fall on permeable, well-drained soils should therefore be confined primarily to nonleachable carriers.

Amount of nitrogen applied. Investigations show that drainage loss of a soluble nutrient is related to the amount of that nutrient in the soil. The loss of nitrate nitrogen will therefore vary with the total amount applied, assuming that none of the nonleachable nitrogen is converted to nitrate nitrogen. Because of the difference in nitrate content, we can expect the loss to be greater when nitrate of soda is applied in the fall than when an equivalent amount of nitrogen, as ammonium nitrate or Solution 32, is applied (see Table 1).

The economic loss sustained when nitrogen is lost through leaching can be measured in two ways: First, there is the actual cost of the nitrogen that is lost. Second, there is the increased crop value that the lost nitrogen might have produced. With small applications the loss is not great regardless of which yardstick you use. But if the leaching loss runs as high as 25 pounds an acre, the loss in crop value may be three times the cost of the nitrogen that leaches out.

Vegetative cover. Plant roots are effective in reducing nitrogen leaching losses. Lysimeter data show that less nitrogen is lost from cropped soils than from adjacent areas where the soil is fallowed. Almost no nitrogen drainage occurs where continuous grass sods are maintained. On the other hand, losses where row crops have been harvested may be fairly large. Thus the kind of crop that is grown has an effect on the amount of nitrogen lost through drainage.

The superiority of grass sods over intertilled annual crops in reducing drainage losses is probably related to the greater density of the grass root system and the longer season over which grass roots actively absorb nitrogen. Nitrogen (even carriers that supply nitrate nitrogen) can be applied in the fall on grass sods without serious leaching loss provided

the grass is growing actively. But when grass is winter dormant the root system no longer absorbs nitrate nitrogen effectively, and nonleachable carriers are preferable.

Legume roots are also effective in absorbing nitrate nitrogen. But applying nitrogen to sods that are predominantly legumes decreases the ability of the legumes to fix nitrogen. If nitrogen is to be applied to legume sods, it should be done after the legume is winter dormant. Leaching losses of nitrate nitrogen due to normal decay can also be minimized by delaying fall plowing of legume stands until mid-September or later.

Residues. Competition between microbes and nonleguminous crops for available nitrogen when residues with wide C:N ratios are plowed under can be eliminated by applying commercial nitrogen. In the process of decay, the commercial nitrogen is converted to nonleachable organic nitrogen. When temperature and moisture are favorable, organic nitrogen forms undergo further microbial decay and release available nitrogen. Applications of commercial nitrogen to highly carbonaceous residues must be timed in such a way that microbial activity will tie up the nitrogen and not release it until the following season.

Since microbes cause decay, it is obvious that soil temperatures must be favorable for microbial activity. Otherwise no tie-up of nitrogen can take place. If soil temperatures are favorable for microbial growth, as much as 30 pounds of nitrogen can be applied per ton of highly carbonaceous residues.

The importance of temperature in this microbial tie-up of commercial nitrogen raises a question about the practice of applying nitrogen to cornstalks in the fall for the express purpose of hastening decay. There is relatively little microbial activity at the time of corn harvest (Figure 1). This being the case, but little nitrate nor ammonium nitrogen can be converted into organic forms before winter. If nitrate carriers are used, leaching losses may occur. On the other hand, nonleachable forms will remain in the soil and the decay process will be completed in the spring when temperatures are again favorable for microbial growth.

Legume residues with narrow C:N ratios contain enough nitrogen for rapid decay. Where nitrogen is to be applied in the fall on legume sods, nonleachable types are to be preferred.

The practice of applying nitrogen to cornfields that are to be planted to soybeans for the purpose of rotting the residues should be discouraged. Soybeans, if properly nodulated, can fix all the nitrogen they need. Although applying nitrogen to cornstalks before soybeans are planted does hasten decay, it also reduces the ability of the soybeans to fix nitrogen. Applying nitrogen under these circumstances is equivalent to applying it to the beans themselves, a practice that is not generally recommended in Illinois. Furthermore, it may cause excessive vegetative growth at the expense of yield.

For further information concerning the reactions of nitrogen in soils, see pages 31-39, "Science and Economics of Soil Fertility" AG1589.

Edward H. Tyner
10-4-54

AGRONOMY FACTS

FERTILIZERS

This is the beginning of a series of articles entitled Fact and Fancy About Fertilizers and Soil Fertility.

It is hoped these articles will answer some of the timely questions being asked by farmers and fertilizer dealers interested in soil fertility and soil productivity. The questions used in this series are purely hypothetical, and the answers are based on present knowledge and present price relationships, both of which are subject to change. Additional material will be prepared as pertinent new questions arise.

* * * * * * * * * * *

Question 1: What does the label on a fertilizer bag mean? For example:

Available Nutrients

N	P_2O_5	K_2O
5	10	10

Answer: It means that each 100-pound bag contains 5 pounds of N, 10 pounds of P_2O_5, and 10 pounds of K_2O. A ton is 20 hundred pounds, so will contain 20 times as much, or 100 pounds of N, 200 of P_2O_5, and 200 of K_2O. This method of reporting them is chemical shorthand designed to reduce different forms to a common denominator. Actually the N (nitrogen) could be present in the form of ammonia, nitrate, or urea, or all three. Usually the ammonia form predominates in mixed goods. Potash (K_2O) is usually present as potassium chloride (KCl). Phosphorus (phosphate) is not present as P_2O_5 but as monocalcium phosphate $CaH_4(PO_4)_2$ or ammonium phosphate or some similar soluble form.

The label also means that the fertilizer has met certain solubility tests; otherwise the word available could not be used.

Question 2: How can I evaluate the worth of a fertilizer?

Answer: While prices vary according to locality and forms of fertilizing materials used, it can be very roughly estimated that a pound of N is worth 15 cents, a pound of P_2O_5 is worth 10 cents, and a pound of K_2O is worth 5 cents.

Here again we are using chemical shorthand. These prices are the basic prices. They are the amounts you would have to pay for them as "straight goods" or "single carriers," e.g., as a bag of ammonium nitrate, superphosphate, or muriate of potash.

Example a. A 100-pound bag of 33-0-0 contains 33 pounds of N. At 15 cents a pound, a 100-pound bag is worth 33 x 15 cents = $4.95. A ton contains 20 hundred pounds, so a ton would be worth 20 x $4.95 = $99.00.

Example b. To calculate the basic value of a 3-12-6 fertilizer:

3 x 15 cents =	$ .45	
12 x 10 cents =	1.20	
6 x 5 cents =	.30	
	$2.95	per 100 pounds

$2.95 x 20 = $59.00 per ton (2,000 lb.)

This calculated value of $59.00 is only the basic price. The actual price will always be higher due to cost of mixing. Basic prices also change from year to year.

Question 3: Are blended materials the same as mixed fertilizers?

Answer: When the manufacturer mixes two or three soluble or available nutrients together to form a product like 0-20-10

or 10-10-10, this is called a mixed fertilizer. Its analysis is guaranteed to be as stated on the bag or tag. Besides being a mixture of the nutrients, it is also "conditioned" so that it will not cake so readily and will flow more freely.

Recently, as a result of the soil testing program, the practice of blending has come into the picture. Often the soil tests indicate a need for mixtures not available as mixed goods. Also, large amounts are being broadcast ahead of the small grain to be seeded to a legume, and bagged material may have no special advantage. In such cases the farmer buys the needed amounts of superphosphate, muriate of potash, and nitrogen fertilizer, like ammonium nitrate or ammonium sulfate, and has the blender mix them together. Often the blender will also spread the fertilizer. Such a mixture is technically not a mixed fertilizer because the term mixed fertilizer applies only to materials already mixed and analyzed and bearing a guaranteed analysis. It should not be called a mixed fertilizer.

The blended material has the advantage of containing materials in the needed proportions, and the cost is usually below that of mixed and bagged materials.

According to law, the blender cannot sell his blend as a mixed fertilizer. Instead, he sells the individual materials. The blending (and spreading) is an extra service subsequent to the buying of the individual carriers. He can sell materials which, when mixed, would be equivalent in amount of N, P_2O_5, and K_2O, for example, to a 10-10-10 but he cannot sell it as a 10-10-10 mixed fertilizer. The blend may not be as thoroughly mixed as a mixed fertilizer. Though absolutely perfect mixing is not essential, careless mixing may decrease the effectiveness of the blend.

Question 4: Will commercial fertilizers be effective when applied to the surface of the soil without mixing, as when topdressing?

Answer: The nitrogen part of a fertilizer is readily used, but the phosphorus and potassium will be mostly adsorbed in the top 1/4- to 1/2-inch of soil. They do not effectively penetrate downward. This limits root feeding, especially when the soil is dry. But it is often done as an expedient when the crop is already established as when fertilizing established pastures. Very sandy soils which do not adsorb nutrients are exceptions.

Question 5: Are some soluble fertilizers so much more efficient than others that they give greater increases and can be used in smaller amounts?

Answer: Look at the guaranteed available analysis. If it is 5-10-5 or 4-8-4 or any other analysis, then it is no different than any other 5-10-5 or 4-8-4, etc. Some brands may spread easier than others, may be physically different, but all will be alike as far as their availability is concerned. There are no "hidden" values in fertilizers. Any value present is always claimed as part of the available analysis on the fertilizer bag. Ignore all claims made in advertising which are not on the bag tag.

Fertilizers of the same composition give, in general, equal effects when equal amounts are applied. When using a small amount of a fertilizer, one is always sure to get the greatest returns per dollar invested. But the object of fertilizer use is to obtain maximum yields and profit per acre, not greatest percentage returns on the money invested. One actually loses money by using small amounts on deficient soils compared to using the full requirement.

Question 6: Does the response one gets when adding a fertilizer have any relationship to the value of the fertilizer?

Answer: No! The response to a fertilizer depends not only on how much is

applied and its composition, but also on how deficient the soil is and how productive it is, among other things. In fact, it depends on all the other factors in production.

If you are practicing maintenance, i.e., if your soil is already fertile, and you are adding fertilizers to keep it fertile, you get no response at all. If the soil is highly deficient, the response will be relatively large for a small amount added. If it is not very deficient, it will be a relatively small response for a large amount added. All of this has to do with the state of your soil, not the quality or value of the fertilizer.

Fertilizers are worth no more than their basic market value. Any response obtained must be credited to over-all good management not just to one item in good management.

Question 7: Is it true that once you start using fertilizers you will have to keep on using them?

Answer: No, this is not true! You can stop using fertilizers any time you want to let yields eventually decline to their former levels or even lower. But if you want yields to continue at higher levels you will have to continue to use the fertilizers which pushed the yields up to these higher levels in the first place. All kinds of fertilizers--limestone, rock phosphate, soluble mixed goods, and single carriers like nitrogen, superphosphate, or muriate of potash, must be continued to be used if yields are to continue.

Yet this question is being asked continually by farmers who have never used fertilizers and are afraid to start using them because they believe they will have to keep on using them. Some believe this applies only to mixed or soluble goods--not to limestone and rock phosphate, but limestone and rock phosphate also have to be used continuously although not as often because more is applied at one time.

It seems strange that this question is asked so often because it is no different from livestock feeding. If you want runts you do not feed much. If you want choice cattle you feed plenty of the right kinds of feed. Yet, no one has ever asked the question "If I start feeding my cattle will I have to keep on feeding them?"

Infertile soils produce "runt" yields. Fertile soils produce big yields. Using fertilizers to produce big yields is only good common sense. But you can stop using them at any time and your soil will be better for their use, not worse.

Question 8: Can nutrients be stock-piled in the soil?

Answer: Phosphates, either rock or soluble phosphates, can be stock-piled in reasonably large amounts if you can justify it. The soil will hold them against loss and even the third generation will benefit if still on the farm.

Potash could be stock-piled on all but the sandy corn-belt soils but it is entirely uneconomical and impractical to do so. This is because the soil minerals are still releasing available potash, making stock-piling unnecessary. Even the return of all that is removed in the crop is unnecessary and uneconomical for the dark-colored soils. Let the soil tests control your potash use.

Nitrogen is in one sense stock-piled when soil humus is increased. However, it is not available until the soil humus again is decomposed. Use nitrogen in amounts adequate for high yields but do not consider building up soil organic matter just for the sake of building it up.

Do not stock-pile limestone! This is disadvantageous in many ways. Use only what is needed.

Do not stock-pile minor elements! They are expensive and act as poisons in excessive amounts. Use only when their need has been verified by a reliable analysis or field trials.

Question 9: How can one evaluate a mixed fertilizer sold as a liquid or solution?

Answer: Suppose the solution fertilizers have an available analysis of 5-10-10. This means that 100 pounds of the liquid (not 1 gallon) contains 5 pounds of N, 10 pounds of P_2O_5, and 10 pounds of K_2O. To calculate the value of a gallon, one must first find out the weight of 1 gallon and calculate how many gallons it takes to make a hundred pounds. Reliable dealers will have this information. Now calculate the basic value of a 5-10-10 as directed under Question 2. Compare this value with the cost of the number of gallons it takes to make 100 pounds. It will be higher due to mixing costs as well as the fact that higher cost materials are used.

Question 10: Does a liquid fertilizer have any advantages over a dry fertilizer?

Answer: Pound per pound of nutrient applied, the liquid fertilizers and the dry fertilizers are equal in value if the costs applied are equal. The basic value for N, P_2O_5, and K_2O used above is for comparing the straight dry materials which are the standard materials.

However, it is the "cost applied" which determines the real cost of a fertilizer. One form might cost the same or even more, but if the cost of the fertilizer plus the cost of application is lower, then the "cost applied" is lower. A good illustration is that of anhydrous ammonia which sells at a much lower original cost than the basic value of 15 cents. However, its cost of application is higher due to power requirements, and the other forms are still in active competition with it.

To compare liquid, dry, or high pressure fertilizers, add the cost of application to the cost of the fertilizer.

R. H. Bray
12-27-54

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

SF-30

SOME QUESTIONS ABOUT THE EFFECTS OF CERTAIN CULTURAL PRACTICES ON THE ACTIVITIES OF MICROORGANISMS

Question: Does the application of anhydrous ammonia cause soil sterilization?

Answer: Anhydrous ammonia is a liquid under pressure. When the liquid is released in the soil, ammonia gas is formed, which dissolves in the soil water and becomes attached to the clay particles (see SF-6).

Applying anhydrous ammonia to soils at the concentrations that are normally used appears to have no harmful effect on the soil microorganisms. On the first day after application there is a slight decrease in total numbers of microorganisms, and there may even be small, localized zones in which the soil becomes partly sterilized. But this effect is only temporary. After the first day, bacteria numbers increase greatly, particularly the nitrate producers. The numbers of actinomycetes also increase.

The injection of anhydrous ammonia causes an initial increase in pH. The result is that the numbers of fungi remain depressed for a longer period of time. As the pH and ammonia levels are lowered by nitrification, the numbers of bacteria, actinomycetes, and fungi return to the levels they held prior to the application.

Question: Does the use of insecticides and herbicides cause soil sterilization?

Answer: In the past few years new insecticides have been developed that are more potent than many of the most efficient germicides and antibiotics. W. B. Bollen, bacteriologist at the Oregon Agricultural Experiment Station, has conducted experiments to see what effects these chemicals have on soil microorganisms and their functions in soil fertility. Here are his conclusions:

"The various insecticides and herbicides produced increases as well as decreases in microbial numbers and some of their important activities in the soil. These effects were found to depend not only upon the specific nature of the pesticidal compound, but also upon the rate of application and soil type. It is significant, however, that not any of the compounds, even when applied in the laboratory at rates far in excess of those recommended for insect or weed control, influenced microorganisms sufficiently to consider the effects important in soil fertility. . . .

"These findings lend assurance to the farmer and agricultural specialist that recommended pesticides, including such important compounds as DDT, aldrin, chlordane, heptachlor, lindane, 2,4,5-T, and IPC, can be used at conventional rates without affecting soil fertility by injuring soil microorganisms. Without such assurance entomologists and other specialists would hesitate to recommend these powerful materials, and agriculture would be deprived of full realization of their benefits."

Thus it seems reasonable to conclude that insecticides and herbicides, when applied at recommended rates, have no harmful effects on soil microorganisms. It should be pointed out, however, that very little is known of the residual effects of some of these chemicals, and repeated heavy applications may prove to be harmful either by causing partial soil sterilization or by developing a characteristic microflora.

Question: How can one account for a scarcity of nodules on vigorously growing leguminous plants?

Answer: There are many factors that influence the production of nodules on leguminous plants. Among them are light, temperature, pH, presence of inorganic salts, supply of available nitrogen, moisture, and numbers of bacteria capable of symbiosis with the host plant. Because the conditions that are most suitable for the host plant are usually also best for nodule formation, the scarcity or lack of abundant nodules on vigorously growing plants can be ascribed chiefly to any one or all of the last three.

It is a well-known fact that if the soil is rich in soluble nitrogen, such as nitrates, the number and size of nodules are reduced. The magnitude of this effect will vary, depending on such factors as moisture, amount of soluble nitrogen, form of nitrogen, and type of leguminous plant. In some cases nodule formation may be inhibited completely, although usually only a decrease in numbers would be expected. For a more complete discussion of the effect of nitrogen content of the soil on nitrogen fixation, see SF-8.

Soil moisture also has a definite effect on the presence of nodules on leguminous plants. If the upper layers of the soil should become too dry during periods of vigorous plant growth, the plant can absorb the nodules. Examination of the roots later in the season will reveal no nodules even though many may have been present earlier.

Unfortunately the appropriate nodule-forming bacteria are not always present in the soil, and under such conditions nodules fail to form. Like any other plant, the leguminous plant must then draw all of its nitrogen from the soil. The conditions under which one would expect not to find suitable numbers of the proper bacteria are when the host plant has not recently been grown on the field or when the soil is, or has recently been, distinctly acid. Nodulation can then be insured by inoculating the soil with the appropriate nodule bacteria. Acid soils should be limed prior to inoculation, and phosphorus and potassium should be added in accordance with recommendations from soil tests.

To get thorough inoculation, the directions printed on the container should be followed precisely. The sooner the seed is planted after treatment, the better. Seeds that are not planted on the same day as they are treated should be treated again before planting.

Obviously the largest response to inoculation will be obtained on soils that lack the proper bacteria, because all of the nitrogen fixed from the air would result from inoculation. Most soils will, however, contain some of the bacteria needed for nodulation. Even so, beneficial results can be obtained by inoculation. For this reason it is recommended that all leguminous seed be treated prior to planting, regardless of the type of plant previously grown on the field. Besides, inoculation is cheap insurance.

Question: Why is sawdust harmful to crop growth?

Answer: Sawdust is a by-product of several wood-using industries. It is used mainly as a top-dressing in nurseries and truck gardens. It is also used as bedding for farm animals.

As a rule, adding sawdust to soils lowers crop yields. The major reason is that sawdust has a low nitrogen content, with the result that nitrate nitrogen is tied up during decomposition (see SF-23). Use of sufficient nitrogen to take care of the needs of the microorganisms will usually correct this condition, although it may also be desirable to add phosphorus and potassium and to lime the soil. Applying nitrogen in an amount equivalent to 1.75 percent of the dry weight of the sawdust will normally insure enough nitrogen for decomposition without

depriving the crop of nitrates (see SF-26). Because the nitrogen content of sawdust is only about 0.15 percent, or 3 pounds per ton, 30-35 pounds of nitrogen per ton of sawdust will be needed to insure decomposition.

Factors other than a low nitrogen content may also contribute to the lower yields, since adding supplemental nitrogen and other plant nutrients has not always corrected the difficulty. Some workers believe that the tannins and other organo-solubles in certain types of sawdust may affect yields. Recent studies on composting sawdust before adding it to the soil have given promising results, but more research needs to be done before concrete recommendations can be made.

F. J. Stevenson and O. H. Sears
11-29-54

NITROGEN

Question 1. Are there any differences in the crop-producing abilities of different forms of available nitrogen?

Answer: If the guarantee claims that the fertilizer contains 10 percent available nitrogen, then it does not matter which particular available form of nitrogen is present. All forms of available nitrogen have the same crop-producing abilities when properly used. The reason is that all forms when added to the soil are subsequently converted by the soil into a common form. All are eventually converted to nitrate nitrogen.

Question 2. Are all forms of available nitrogen applied in the same way?

Answer: No. Each form must be applied with due regard to its properties. Solution forms which contain no "free" ammonia can be sprayed on the soil or dribbled out onto the surface of the soil. Solution forms containing some free ammonia should not be applied directly on the surface without simultaneous mixing. (It is preferable to drill them.) Anhydrous ammonia is under high pressure and must be released far enough below the surface to allow it to react with the soil. Dry forms can be applied in any desired way--broadcast, drilled, or plowed under.

Question 3. Are some forms of nitrogen preferable to other forms?

Answer: Generally no one form is preferable. All forms have the same crop-producing abilities, but there are some points that should be mentioned. For example, soils which leach readily can be treated with the ammonia forms or any forms that change rapidly to ammonia in the soil. The ammonia attaches itself to the soil clay. This reduces the possibility of its being lost by leaching. Nitrates applied in the fall, if not used by crops or in decomposing organic residues, may be lost by leaching before spring growth can use them.

Question 4. Will spraying nitrogen fertilizers on corn, wheat, or similar crops be advantageous?

Answer: Certain forms of nitrogen, if used with caution to prevent burning of the foliage, can be sprayed on the leaves of plants. The leaves will take up some of the nitrogen directly. The rest gets into the soil and is taken up by the roots.

For some situations this might have an advantage. It has been found advantageous for certain fruit trees under some conditions. An unconfirmed report states that waterlogged, nitrogen-treated corn which had turned yellow was given a better start when sprayed with nitrogen than when not sprayed. This is a very special situation. However, in general one must consider that it still takes 140 pounds of nitrogen to produce a 100-bushel crop and that a few pounds per acre applied as a spray can have little effect on the final yield, besides being an expensive way to use nitrogen.

Question 5. Is nitrogen which is sprayed on the leaves of a crop used more economically than nitrogen applied to the soil?

Answer: If the nitrogen applied all got onto the leaf (which is impossible) and were all taken up through the leaf, it would still take 1.4 pounds of nitrogen for each bushel of corn. The plant does not use this nitrogen more economically

in its growth processes. However, if it did adsorb all the nitrogen applied in this way and if the soil-applied nitrogen were partly used by biological reactions in the soil (renewing soil organic matter), then it would take more soil-applied nitrogen to give the crop its 1.4 pounds of nitrogen per bushel of corn.

That the leaves could catch all the sprayed nitrogen and adsorb all that they catch is not even a remote possibility. Spraying nitrogen on the leaves, except for special situations, is so far as is known just another way of applying nitrogen, and a rather expensive way.

Question 6. How much more can I afford to pay for nitrogen to be applied as a spray?

Answer: Only a small part of the total nitrogen that is needed can be applied as a spray at one time, and several sprays will be needed. This increases the cost of application. Since there is no evidence that sprayed applications generally have any ultimate advantage over adequate amounts applied to the soil, one cannot afford to pay any more per pound of N for spraying than for soil applications. However, there may be some exceptions.

Question 7. I have been quoted a price for liquid nitrogen by the gallon. What is it worth?

Answer: Never buy any fertilizer, liquid or otherwise, except by weight. Get a bill of sale, and be sure your bill of sale mentions not only the weight of material you get, but also its composition. Buy all nitrogen fertilizers by the pounds of nitrogen they contain. A gallon of nitrogen solution may contain only one pound of nitrogen. If so, it is worth around 15 cents. Always ask how much actual N is in the material you buy. Never buy by the gallon. Always have the number of gallons you buy figured in terms of <u>pounds of N</u>, and pay for a certain number of pounds of N--not for a certain number of gallons of unknown composition.

Question 8. Do nitrogen fertilizers evaporate from the surface of the soil?

Answer: No. When nitrogen is applied as a solid on the soil surface, it only appears to disappear because it takes up water and blends with the soil. Only when nitrogen is present as free ammonia under pressure is it subject to loss if not mixed. Solutions containing <u>free</u> ammonia should not be applied to the surface of the soil as a general rule. The conditions under which low-pressure solutions containing <u>free</u> ammonia might perhaps be surface applied have not been studied, but they would involve simultaneous mixing with the soil in some manner.

R. H. Bray
1-3-55

ROCK PHOSPHATE

Question 1: Why is the analysis of rock phosphate reported as "total P_2O_5" rather than "available P_2O_5"?

Answer: In fertilizer language the term "available" means soluble. To change rock phosphate into a soluble form is an expensive process. The label "available P_2O_5" on a fertilizer is a guarantee that the phosphate is present as soluble phosphate rather than as the original rock phosphate.

The label "32 percent total P_2O_5" on rock phosphate means that in every hundred pounds of the material there are 32 pounds of P_2O_5. This is present as $Ca_3(PO_4)_2 \cdot CaF_2$ or a similar composition. This does not mean that rock phosphate is not available to crops. True, soluble phosphates are more available in the soil, but rock phosphate is also available although its availability is of a limited nature. Certain plants on limed or only slightly acid soils cannot obtain enough for maximum yields regardless of how much rock phosphate is added. The fertilizer law which makes this distinction is for your protection. You would not want to pay soluble phosphate prices for rock phosphate. The idea that the fertilizer laws in different states were made to discriminate against rock phosphate is too ridiculous to require further discussion.

Question 2: How is rock phosphate evaluated?

Answer: The value of agricultural rock phosphate depends in part on the fineness of grinding. However, all commercial rock phosphates have met certain minimum fineness requirements and can be evaluated on the basis of the total P_2O_5 they contain. At present Illinois prices the P_2O_5 in rock phosphate costs around 2.8 cents a pound. Therefore, a 32 percent P_2O_5 material will be worth about

$$32 \times \$0.028 = \$0.90 \text{ a hundred}$$

$$20 \times \$0.90 = \$18.00 \text{ a ton}$$

Question 3: If a 32 percent rock phosphate costs $18.00 a ton, what is a colloidal (waste pond) rock phosphate containing 21 percent P_2O_5 worth?

Answer: The P_2O_5 in waste pond rock phosphate is evaluated in the same way as in the regular rock phosphate.

$$21 \times \$0.028 = \$0.588 \text{ a hundred}$$

$$20 \times \$0.588 \doteq \$11.76 \text{ a ton}$$

Question 4: Is colloidal rock phosphate finer and worth more per pound of phosphorus than the regular rock phosphate?

Answer: The particles of rock phosphate in colloidal rock phosphate are finer, but that it is worth more has never been proved. Fineness of grinding experiments in general have not demonstrated significant differences in the value of rock phosphate for variations in fineness within the fine range. Look on the label. If the label does not claim any available P_2O_5 content and has only a total P_2O_5 guarantee, it is the total P_2O_5 content that is your only guide to its value. See answer to Question 2. The clay in the colloidal rock phosphate is worthless, and the minor element contents of both the regular and the colloidal are extremely small and can be disregarded for comparison purposes.

Question 5: Are legumes needed to make rock phosphate available?

Answer: No. Although legumes may feed a little more efficiently on rock phosphate than some other crops, they are not required to make the rock phosphate available for the other crops. All crops feed directly on rock phosphate, even though some may not obtain their maximum needs from it.

Actually the amounts removed by the other crops are several times the amount returned in the legume. For example, a 100-bushel corn crop contains, in the stalks alone, almost twice as much phosphorus as is contained in 1 1/2 tons of legume hay.

Question 6: Is rock phosphate desirable for blends?

Answer: Since blending is merely one way of getting the needed materials together so that they can all be applied at one time, any of the ordinary materials can be blended. For example, if the recommendation called for 1,000 pounds of rock phosphate and 200 of 0-0-60, there is no reason why they cannot be blended and applied together if broadcast.

However, rock phosphate mixed in with nitrogen and potash fertilizers does not produce a blend that can be used in the same way as soluble mixed fertilizers. The factory-mixed fertilizers contain soluble phosphates which have an effect that cannot be duplicated by rock phosphate. For example, blends containing their phosphate in the forms of rock phosphate are worthless for protecting corn against a 20- or 30-bushel loss due to grape colaspis. When they are used for wheat, a loss in yield as high as 13 bushels can occur. These losses are due to the fact that rock phosphate gives no starter effect. It does not get the wheat off to a good start, and only soluble phosphates can prevent grape colaspis damage on corn.

So the use of rock phosphate only in a blend for drilling in with corn or wheat is not a desirable practice. However, it can be put into a blend to be broadcast when the only object is to get rock phosphate applied to the land. Just remember that it does not take the place of soluble fertilizer phosphate, and that rock phosphate should be broadcast, not drilled.

Roger H. Bray
1-24-55

(This is the 3rd of the series: FACT and FANCY About Fertilizers and Soil Fertility.)

MINOR ELEMENTS

Question 1: Are minor element fertilizers worth while?

Answer: Only if the soil is deficient in a particular minor element is it worth while to use that element. When a soil already contains adequate supplies of the minor elements, their addition is certainly not worth while for the immediate future and would be a very poor long-time investment. Do not stock-pile minor elements which are not deficient! Corn-belt soils generally contain large excesses of the minor elements. But boron is sometimes deficient for alfalfa. Manganese has been found to be deficient in some muck soils in Indiana. Leached sandy soils would be expected to be the first to show minor-element deficiencies, but so far no cases of minor element deficiencies, other than boron, have been found in Illinois.

Somehow the impression has been created that because minor elements are essential to the health of man and animal, they must be added to soils. Potash and phosphate are also just as essential, and yet we do not recommend their use on soils which are already well supplied. Minor elements must not be added to soils that are already well supplied because, when present in too large an amount, they can actually act as poisons for both plant and animal.

The general use of minor-element mixtures has not been found necessary in the Corn Belt.

Often fertilizing materials will contain very small amounts of one or another of the minor elements. These small amounts add nothing to the crop-producing value of the fertilizer if the soil already contains more than enough. If they occur in traces as insoluble materials, they add nothing worth while even though the soil is deficient. The fact that *one* minor element is deficient does not justify the use of a mixture of minor elements. Do not stock-pile minor elements!

Question 2: Can a spectrographic analysis reveal whether or not a soil is deficient or sufficient in minor elements?

Answer: If the spectrographic analysis is a *total* analysis of the soil, it is worthless for measuring deficiencies. To be of any value, it must measure the amounts of the *available* forms, and it must measure them accurately.

So far as is now known, no service for accurately measuring the amounts of all the available forms by spectrographic methods is being offered at the present time. To offer such a service one must first demonstrate (prove) that

1. The form being measured is the available form.

2. The spectrographic method is measuring it accurately.

In addition one must know how much *is* enough, *i.e.*, what values represent the deficient range and what values represent adequate or surplus amounts. Since much of this information is still unknown, no one can claim to be able to spectrographically analyze a soil and determine the available amounts of all the essential elements. Hundreds of thousands of dollars worth of minor element fertilizers have recently been used in this country on soils that are not deficient in any one of them. Progress is being made on methods which, when perfected and calibrated, will eliminate

this waste. But until they are perfected the only guide one can follow is information from the Agricultural Experiment Station. Ask your farm adviser (or county agent) for advice on minor element use.

Question 3: Are there any methods for determining minor element deficiencies?

Answer: A method for boron, using hot water as the extractant, is now being generally used. This estimates the available supply, not the total. The values obtained have been correlated with response to boron.

An experimental method for available zinc has been devised. It uses a mold (Aspergillus) as the indicator. The amount of growth of the mold is a measure of the available zinc. It is not yet being used for soil testing. Chemical methods for available zinc are still in the experimental stage and are too tedious to be very practical at present. No specific correlation has yet been perfected.

A promising method for available copper is being investigated.

Manganese tests would be easy to run if only one knew just what extraction method would give correlations with manganese needs.

When soils are deficient in minor elements and they are being added, it becomes expedient to use tests to determine excess amounts. Here the problem is not to determine the deficiency, but to prevent the accumulation of toxic concentrations.

Roger H. Bray
2-7-55

(This is the 4th of the series: FACT and FANCY About Fertilizers and Soil Fertility.)

AGRONOMY FACTS

MISCELLANEOUS

Question 1: Is ground granite or ground rocks of any kind any good as fertilizer?

Answer: Rock phosphate is technically a ground rock, but its usefulness has been established by long-time research. It is a very special product.

Most rocks are mixtures of silica and silicate minerals, which decompose only very slowly. They often contain small percentages of K_2O, M_gO, and CaO. When they are finely ground, some of the mineral structure is destroyed and some of the K_2O, M_gO, or CaO is made more soluble.

For example, a finely ground granite might contain as much as 5 percent K_2O in a soluble form. Its basic value would be 5 x .05 = 25 cents a hundred, or 20 x 25 cents = $5 a ton. So if its guaranteed available analysis is 0-0-5, then its basic value is only $5 a ton. But in this case its actual value is really less than its basic value because one would have to haul and apply a whole ton of the material in order to apply potash equivalent to 166 pounds of 0-0-60.

The rest of the potash not released by grinding is of no more value than, and of the same general nature as, the 20 thousand pounds of K_2O already present in the surface 7 inches of an acre. Adding more is like "carrying coals to Newcastle."

With present freight, hauling, and spreading costs, a low-analysis fertilizer can be practically worthless or even a liability compared with basic fertilizers like ammonium nitrate, superphosphate, and muriate of potash. In short, a fertilizer can be economically worthless when it has too low a composition.

Vague claims of "other values," "residual values," "minor elements," etc., can be ignored. To be given any credit, any such value must be listed under "percent available." Any nutrient listed as "percent total" has no immediate and in all probability no future value. Rock phosphate is an exception to this rule.

Question 2: Suppose a salesman tried to sell me a material guaranteed to have exchange properties and guaranteed to hold most of the available nutrients in the soil and prevent their being leached away. Are there such materials?

Answer: Yes, there are such materials, and they can hold the available nutrients against leaching. A salesman could sell you such materials and make his claims stick.

The catch to this is that almost all soils already have too much of these kinds of materials. Even Illinois sands have enough. These materials are the soil humus and the soil clay, which hold such nutrients as potassium, phosphorus, ammonia, calcium, magnesium, and most minor elements. So do not buy "base-exchange materials" or "zeolites" for your soil. Certain sands in Florida do have too little, but it would take over 10 tons of a high base-exchange clay to make a worth-while increase in their exchange capacity. So far as is known, no one has tried to sell such materials in the Corn Belt. This question was asked just to illustrate how easy it is to make something sound highly practical when in reality it is not needed and hence is worthless.

Question 3: What is virgin soil? Would it be a good fertilizer?

Answer: Virgin soil is soil which has never been plowed and is still covered by the original prairie or forest vegetation.

No, virgin soils, even though highly fertile, are not fertilizers. True, they contain, as the plowed soils still do, large amounts of ground rocks of all kinds and large supplies of humus. A supply of active organic matter in the form of partially decayed grass, etc., makes them highly productive at first.

There are one thousand tons of soil in the plowed depth of an acre. Adding one ton or even 10 tons of a fertile virgin soil to one thousand tons of infertile soil would so dilute the virgin soil that its effect would be economically worthless. Any results that were obtained could usually be duplicated by adding nitrogen at a much lower cost. Any good compost would be highly superior to a virgin soil, whether it is an original virgin soil or a synthetic virgin soil. Claims that such soils produce disease- and insect-free crops because of the nature of the soil itself have never once been verified scientifically. The scientific method of check and countercheck is your safeguard against exploitation. Check with your farm adviser or county agent when in doubt about a new product.

Question 4: A salesman tried to sell me what he said was a new fertilizer. As nearly as I could understand, it was gypsum and was to be used at the rate of 1/2 to 1 ton per acre. Is it a fertilizer, and do I need it?

Answer: Gypsum or land plaster is crude calcium sulfate. It is also being sold under other coined names. Both calcium and sulfur are essential nutrients. But this does not mean that gypsum has to be added as a special fertilizer.

Corn-belt soils are not sulfur-deficient soils. When soils are deficient in sulfur, the calcium sulfate in the superphosphate takes care of the deficiency. Only when high-analysis soluble phosphates containing no sulfates are being used on sulfur-deficient soils is it desirable to add extra calcium sulfate in small amounts.

When soils are not deficient in sulfur, calcium sulfate not only is worthless as a fertilizer, but may actually be harmful when added in large amounts. It does not neutralize acid soils, and sweet soils do not need the calcium. It is soluble enough to leach away; hence it is not advisable to use large amounts, since it cannot be stock-piled. Furthermore, in leaching away, it will replace potassium and magnesium and cause their loss by leaching.

So on a typical limed corn-belt soil today, the application of any relatively large amount of calcium sulfate, whatever name it goes by, will or not do the following:

1. It will not supply any needed nutrient.

2. It will not neutralize the acidity of the soil.

3. It will increase the leaching loss of potassium and magnesium.

The use of gypsum for soil conditioning has not been sufficiently studied on corn-belt soils to make any statement about its probable effects.

Question 5: Is it practical to spray complete fertilizers on the leaves of the growing crop?

Answer: As a general practice it is not economical to spray complete fertilizers on the leaves of growing crops. The amount that does not cling to the leaves falls onto the ground and, except for the nitrogen, is much less available for that year's crop than the drilled fertilizers. The part that is washed off by rains is likewise reduced in availability. The part that is adsorbed by the

leaves has no more value than if it has been adsorbed by the roots from the soil. It takes many applications to apply any appreciable amount of fertilizer, and the cost of each application must be included as part of the cost of the fertilizer. Remember, a 100-bushel corn crop contains around 140 pounds of N, 53 of P_2O_5, and 94 of K_2O. Spraying fertilizer on the leaves does not change the needs of plants.

Spraying each acre with 40 gallons of liquid, containing 1/2 pound of N per gallon would require 7 to 8 applications just for the nitrogen. Ninety-four pounds of K_2O and 53 of P_2O_5 applied as a spray would likewise be a tremendous amount to expect the leaves to hold and adsorb.

Of course, these amounts can be decreased by the amounts which will be contributed by the soil. But since, in the long run, the cost of producing a crop is only the cost of P_2O_5 and K_2O removed by the crop, and since the other forms of fertilizer are cheaper to use (buy and apply), fertilizing the soil is the best and most economical long-range program.

But there are situations where it might be desirable to spray nutrients. For example, a minor-element deficiency appearing on a crop can sometimes be overcome by spraying. This is usually an expedient rather than a recommended practice. One should not purposely leave a soil deficient and spray only after deficiency symptoms occur, since this means some yield losses even though the deficiency is corrected eventually.

Roger H. Bray
2-14-55

(This is the 5th of the series: FACT and FANCY About Fertilizers and Soil Fertility.)

AGRONOMY FACTS

SF-35

HOW TO MEASURE A SOIL'S PRODUCTIVE POSSIBILITIES

There is one thing every farmer should know about his own soil. It is the soil's ability to produce when all nutrients are adequate. If he knows his soil's productive possibilities, he will know what yield levels to aim at when planning his fertilizer use program. Knowing what yield to aim at is especially necessary when estimating nitrogen needs.

The majority of Illinois farmers have been taking yield cuts of 30 to 40 bushels of corn merely because they do not realize the potential productivity of their own soils. Many mistakenly believe that there is nothing they can do about increasing yields unless they go into a legume rotation program. The physical conditioning effect of a good legume rotation is, however, only a minor, although important, part of its effect; the nitrogen provided by the legume is the major effect.

This major effect can be obtained equally as well by using nitrogen fertilizers, and most legume programs have failed to provide adequate nitrogen. This is especially true of those designed for a grain system of farming. So even though a legume rotation is being used, the following trial is still recommended as a test of the soil's productive capacity when all nutrients are adequate.

The fertileness of a soil is more than just the supply of plant food it contains. This is only the chemical fertileness. It is very easy to make a soil chemically fertile. Yet all chemically fertile soils do not yield the same amounts. In fact, the top yield a soil can give is no more determined by chemical fertility than the top weight a steer can reach is determined by the amount of feed it gets.

Agronomists have a name for this top yield. They call it yield possibility and it is the yield obtained when all nutrients are adequate but are not present in harmful excess. Top yield or yield possibility is controlled only by the variety or hybrid that is grown, the thickness of planting, the physical favorableness of the soil (physical fertility as contrasted to chemical fertility), and the favorableness of the season. The yield possibility of a soil is not the same each year because the seasons vary. These yearly variations will be due mostly to variations in rainfall and its distribution.

Physical favorableness, and hence the yield possibility of soils, will vary with the kind of soil, the lay of the land, and the way in which it has been managed. But, surprisingly enough, soil type variations do not produce such big differences as we once thought they did.

Making soils fully fertile has narrowed the differences in yield once believed to be due to soil type. But adjacent fields on the same soil type can differ in physical favorableness, and hence in possibility, as a result of past management.

This leaves the variety or hybrid and how it is planted still to be considered. Some varieties produce higher yields than others. Some can stand thicker planting than others. Highest yields come from those that are both high yielding and can stand fairly thick planting. In corn, too thick planting can cause a decrease in yield because the weight of the ears then decreases rapidly.

Corn is a good crop to use to measure the over-all productivity, or yield possibility, of a fertile soil, because almost every farmer in the Corn Belt is growing or has grown corn. The following suggestions are for those who are interested in seeing what their soil is

really capable of producing. They should be tried on a couple of acres only, because the suggested treatments are not given as a practical fertilization program. They are solely for the purpose of making sure that, regardless of original fertility, all possible nutrient deficiencies are overcome so that the true yield possibility of the soil can be determined.

1. Select a couple of acres that will represent the soil on the whole farm. Do not use an area you already know to be superior. If the soil on the area you choose is superior to that on the rest of the farm, it will represent only a small part of the farm.

2. Have the soil tested for lime requirement, and spread limestone according to test (unless it is already adequately limed).

3. Before plowing, broadcast 500 pounds of muriate of potash (60 percent K_2O) and 800 pounds of superphosphate (20 percent P_2O_5) or its equivalent as a more concentrated soluble phosphate. Also broadcast 600 pounds of ammonium nitrate (33 percent N) or its equivalent in terms of nitrogen. These are the amounts to apply per acre. You will need twice as much of each for the two acres.

4. Disk all of these materials into the soil as deeply as possible in order to get them well mixed with the soil. Disk again crosswise.

5. Plow and prepare a good seedbed.

6. Use the customary planting pattern, i.e., hill or row.

7. Plant one acre at the rate of 12,000 kernels per acre and the other acre at the rate of 16,000 kernels.

8. Keep the soil free of weeds.

9. Before harvesting make counts of the stand and the numbers of barren stalks or ones with only very small nubbins.

10. Harvest the whole of each acre with its different planting rates as a measure of the yield possibility (not the best two rows).

The yield that is obtained on each acre will be the yield possibility for each rate of planting. It measures that soil's ability to produce that year. It might be higher in a more favorable season. It will be lower in a less favorable season. Making such trials on the same farm over a period of years will give the average yield possibility of the soil.

The reason two rates of planting are included is that rainfall or water supplies vary. In some years the rainfall and its distribution may be sufficient to cause the higher rate of planting to give the highest yield. In years when rainfall distribution is less favorable, the yields may be higher with the lower rate of planting. One can overplant and use too much of the water in making more stover than grain. On soils of good physical quality, it is rainfall and not the soil that limits yields. You can expect that between the soils of better physical quality yield possibilities will not differ greatly, because rainfall will be the limiting factor. Any differences that are obtained will be due to differences in the soil's capacity for holding water and furnishing it to the crop.

Do not be surprised if the yield possibility turns out to be almost twice as large as or larger than the yields that have been obtained previously. On the average farm this is to be expected.

But if you want to make the rest of the farm as productive as these two acres, do not follow the fertilizer recommendations given above. Instead, have each field tested for lime requirement and for available phosphorus and potassium so that the fertilizer program can be based on what you know is already present in the soil. The amount of nitrogen to apply will be based on the average yield possibility and cannot be less than that contained in the crop removed from the field. In a 100-bushel yield, this would

be 100 pounds of nitrogen at the very minimum as maintenance, and even more when you first start the program.

It is not our purpose in this article to outline any system or program of fertilization. The sole purpose here is to explain the value of knowing the yield possibility of the soil and to give as simple directions as possible for its measurement.

Do not take your first year's results as the whole answer, especially if you have either a very good season or a very poor season. Remember, a good yield in a season of well-distributed rainfall will not be the average yield possibility. You can expect to get as high as 130 bushels or more on the better dark-colored soils of the Corn Belt in extra good seasons. Hundred-bushel yields should be common in extra good seasons even on the light-colored soils of southern Illinois. In fact, the above formula was first used on the acid soils of southern Illinois in a year that happened to be very favorable. All who planted around 16,000 kernels per acre obtained over 100 bushels. Those planting at either lower or higher rates obtained lower yields. Yet somewhat similar treatments in 1954 in southern Illinois produced only about 20 bushels of corn on shallow "slick spot" soil because it was a very dry year and the soil held moisture poorly.

On the other hand, one farmer in Whiteside county has a long-time average of over 130 bushels for his whole farm. This represents his average yield possibility. It is high because of three things: he keeps his soil fully fertile, he plants good hybrids at optimum rates, and his farm is located in a part of the state in which both the rainfall distribution and the soil are particularly favorable.

R. H. Bray
4-4-55

RELATION OF RATE OF PLANTING AND NITROGEN TO YIELD AND COMPOSITION OF CORN GRAIN

The results shown in the table on the back of this sheet were obtained on a fertile soil near Urbana with Funk's G-94 corn hybrid in 1948. This season was very favorable for corn production, and the results represent approximately the maximum yield of grain and the maximum change in percent of grain protein that can be obtained with these rates of planting and nitrogen levels. Similar results could not be obtained except in a favorable season.

The data bring out these several important points:

1. Except for one or two plants per hill, yield increased for each rate of planting as soil nitrogen increased. The largest increases in yield for increasing nitrogen occurred at the two highest rates of planting.

2. Except for four and six plants per hill on the no-nitrogen plot, yield increased at each level of soil nitrogen as rate of planting increased. The increases were largest at the highest nitrogen levels.

3. With few exceptions, percent of protein in grain increased at each rate of planting as soil nitrogen increased.

4. With few exceptions, percent of protein in grain decreased at each level of soil nitrogen as rate of planting increased. The decreases were smallest at the highest nitrogen levels.

5. Percent of oil, phosphorus, and potassium were affected very little by either rate of planting or soil nitrogen.

E. B. Earley
4-11-55

AGRONOMY FACTS

SF-36

RELATION OF RATE OF PLANTING AND NITROGEN TO YIELD AND COMPOSITION OF CORN GRAIN

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E. B. Earley
4-11-55

Relation of Rate of Planting and Soil Nitrogen to Yield and Composition of Corn Grain of Funk's G-94
Urbana, Illinois, 1948

Plants per hill & per acre	Factors studied	PKa/ + lb. N/A.b/ No N	40 N	80 N	160 N	Av.
1 at 40"c/	Yield, bu./A.d/	60	62	69	67	64
(3920)	Protein, pct.e/	9.9	10.7	10.8	10.7	10.5
	Oil, pct.	4.65	4.63	4.50	4.54	4.58
	Phos., pct.	.27	.29	.29	.27	.29
	K, pct.	.33	.33	.33	.32	.33
2 at 40"	Yield, bu./A.	96	101	109	104	102
(7841)	Protein, pct.	9.1	10.0	10.6	10.7	10.1
	Oil, pct.	4.50	4.66	4.68	4.76	4.65
	Phos., pct.	.26	.26	.26	.26	.26
	K, pct.	.32	.32	.32	.33	.32
3 at 40"	Yield, bu./A.	113	125	135	139	128
(11,761)	Protein, pct.	8.4	8.9	9.7	10.5	9.4
	Oil, pct.	4.56	4.80	4.56	4.56	4.62
	Phos., pct.	.28	.24	.25	.25	.26
	K, pct.	.32	.32	.32	.31	.32
4 at 40"	Yield, bu./A.	108	138	149	156	138
(15,682)	Protein, pct.	7.8	8.3	9.3	10.0	9.0
	Oil, pct.	4.43	4.54	4.68	4.66	4.58
	Phos., pct.	.27	.24	.24	.24	.25
	K, pct.	.32	.29	.31	.30	.31
1 at 10"	Yield, bu./A.	102	125	146	159	133
(15,682)	Protein, pct.	7.9	8.2	9.1	9.8	9.0
	Oil, pct.	4.48	4.53	4.56	4.66	4.56
	Phos., pct.	.28	.26	.24	.24	.26
	K, pct.	.33	.33	.32	.31	.32
2 at 20"	Yield, bu./A.	107	126	149	165	137
(15,682)	Protein, pct.	7.7	7.8	8.8	10.1	8.7
	Oil, pct.	4.52	4.42	4.70	4.63	4.57
	Phos., pct.	.27	.24	.23	.24	.24
	K, pct.	.33	.31	.30	.29	.31
3 at 20"	Yield, bu./A.	117	143	155	184	150
(23,522)	Protein, pct.	7.8	8.0	8.6	9.5	8.6
	Oil, pct.	4.52	4.47	4.57	4.56	4.53
	Phos., pct.	.28	.25	.23	.23	.25
	K, pct.	.33	.32	.31	.30	.31

a/ 600 pounds per acre of 0-14-7 plowed under.
b/ Ammonium nitrate equivalent plowed under.
c/ Corn rows 40 inches apart.
d/ No. 2 corn containing 15.5 percent moisture.
e/ Percent nitrogen x 6.25.
All analyses are reported on the moisture-free basis.

EBE:mm
1-27-55

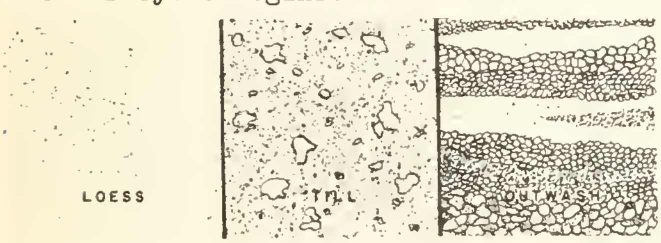
HOW OUR SOILS DEVELOPED

SP-1

The soils of Illinois are so diverse that if they occurred at random they would present an almost hopelessly complex geographical pattern. However, soils do not occur at random nor are their physical, chemical, and biological natures a matter of chance. Our soils have grown or developed in place as the result of several soil formation factors. They have not been moved or transported in their present forms and to their present locations by any natural or supernatural agency.

Soils are the products of five primary factors, and one soil differs from another only because one or more of these developmental factors are different. In other words, all soil units will be alike, within recognizable limits, if they developed (1) from exactly the same kind of parent material, (2) on the same topography or slope or "lay" of the land, (3) under the same cover of native vegetation, (4) throughout the same length of time or to the same age or degree of weathering, and (5) under the same climatic environment.

Any change in one or more of the formation factors or any major disturbance or alteration of the soils themselves brings an end to that cycle of development, and another cycle begins.

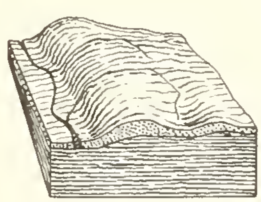


The starting point from which soils develop is called parent material. Given a long enough time, soil will develop from any exposed earth material, even including solid bedrock, such as basalt, granite, limestone, sandstone, etc.

The most common soil parent materials in Illinois are:

1. Loess or wind-deposited silt.
2. Glacial till, or unstratified mixtures of glacier-deposited clay, silt, sand, gravel, and/or boulders.
3. Outwash, or stratified valley train, outwash plain, and lakebed water-deposited clay, silt, sand, and/or gravel.
4. Stream alluvium, or recently deposited bottomland sediments.
5. Limestone, sandstone, shale bedrock, and rock residuum.
6. Organic matter, or peat and muck.

Other things being equal, materials of medium texture, such as loam and silt loam, develop into the most desirable and most productive soils, whether they are of loess, till, or outwash origin. In Illinois, however, loess tends to be the most desirable single soil parent material because it has a very favorable texture as well as a better balanced mineralogical composition than glacial till, outwash sediments, or rock residuum.



Topography is important in soil development because it not only influences depth to water table but, along with permeability of the soil material, determines the amount of water from rainfall that penetrates the soil. Thus it influences oxidation and decomposition of the soil minerals.

Topography is most important where the soils are moderately permeable. Here depth to water table, and hence oxidation and soil color, vary directly with slope. That is, in depressions the water table is shallow or near the ground surface

much of the time and dull gray colors dominate where they are not obscured by the black color of accumulated humus or decayed organic matter.

On steep slopes and narrow ridge tops, the water table is deep, and bright yellowish-brown or reddish-brown colors dominate; while on gentle to moderate slopes, where the water table fluctuates, mixtures or mottlings of grays and/or yellowish-browns along with other colors prevail again where they are not obscured by dark humus.

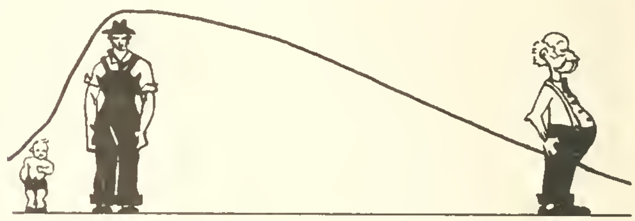
Even where permeability is very rapid, as in coarse textured sandy-gravelly soils, or very slow, as in fine-textured clay soils, topography or slope gradient tends to determine the amount of rainfall available for penetration by influencing the rate of runoff.

Native vegetation is considered a factor in soil development because it is responsible for most of the organic portion of our soils. Bacteria, earthworms, etc., of the animal kingdom, while of importance in hastening the decay and breakdown of organic debris, actually contribute little to the total supply of organic matter in the soil.

In Illinois two types of native vegetation have been of primary importance in the development of our soils, namely, deciduous hardwood forest and tall grass prairie. Other minor types of vegetation are fresh-water swamp plants, weeds, herbs, vines, etc.

Forest or tree and shrub vegetation produces nearly all of its organic debris above the surface of the ground in the form of leaves and twigs. This material lying on the soil surface oxidizes and decays rapidly and almost completely, only a small residue remaining to become part of the soil. Thus most soils developed under forest cover in this state have a thin, dark-colored topsoil layer that is seldom thicker than 2 or 3 inches regardless of parent material or slope.

Prairie grasses, on the other hand, add large quantities of organic matter through their fibrous root systems. This organic matter is incorporated in the upper 1 to 2 feet of the soil itself, where it tends to stay and continues to accumulate as long as the soil is not acid and depleted of plant nutrients.



With the passage of time, soils continue to weather and to develop and are said to age, somewhat as humans do. As the soils develop, each individual physical characteristic becomes more distinct and hence easier to see and identify. The chemical, biological, and mineralogical changes occur in recognizable stages. Organic matter first accumulates and then is dissipated, as are the plant nutrients. Rock and mineral fragments are broken down to smaller and smaller particles, many to clay size. Soil acidity increases, and permeability to water decreases.

Just as humans develop rapidly from babyhood to productive adulthood and then change more slowly to less productive old age, so soils tend to increase rapidly in productivity in their youth because of the release of mineral plant nutrients and accumulation of organic matter, and then with increasing age slowly decline to lower and lower productivity as nutrient depletion overbalances nutrient release and accumulation. Just

as humans differ in how rapidly they develop, how productive they become, and how soon they decline to old age, so soils vary in their rate of development, maximum level of productivity, and rapidity of decline to lower productivity levels.

For example, soils derived from acid sandstone, while perhaps not developing much faster, certainly never naturally become as productive as those derived from limestone, other factors being equal. They also decline in productivity much more rapidly than soils derived from limestone. Soils occurring in slight depressions where excess rainfall accumulates, but where good underground drainage outlets permit this extra water to pass down through the soil, weather faster and reach a more advanced stage of development sooner than associated soils that have a more permanently high water table or that occur on the adjacent slopes. In Illinois this latter condition is well illustrated by the presence of acid, slowly permeable, low-producing gray spots associated in the same field with nearly neutral, moderately permeable, high-producing, dark-colored soils.

One important difference between human growth and development and soil weathering and development is that some soils are kept more or less permanently youthful by the continued removal of weathered material by erosion. Some may be kept more productive and others less productive than they would have become if erosion had not interfered. Many soils are believed to have changed the direction of their development as the result of a change in environment; and man is now undoubtedly causing changes in the development of many soil units by his chemical and mechanical practices. A further important difference is that soil age must be reckoned by thousands and tens of thousands of years.

Climate is the active agency of weathering. Rainfall, temperature changes, air movement, and sunlight are all directly or indirectly responsible for the breakdown of rocks and minerals, the release of plant nutrients, and the development of soil.

Water is the dissolving and leaching agent as well as the transporting agent of materials in solution and suspension. Up to a certain point heat speeds up chemical weathering and biological activity and thus hastens soil development. Freezing locks up released plant nutrients and slows down chemical weathering and biological activity. Oxygen, one of the principal components of air, combines in many ways with the organic and inorganic, released and unreleased mineral elements to form important compounds that are usable directly or indirectly in soil formation, while nitrogen and carbon dioxide, also major components of air, are used by plants and eventually become important components of soil organic matter.

A knowledge of soil types is very useful in determining the requirements of sound soil management for specific areas and in interpreting the results of research for specific soil conditions. A knowledge of the five principal soil-forming factors is basic to predicting the occurrence and extent of individual soil units.

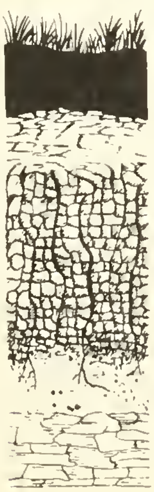
H. L. Wascher
12-20-54

WHAT DO WE SEE IN A SOIL PROFILE?

Soil is a naturally developed, three dimensional body making up the outer portion of the earth's crust. It has depth or thickness as well as surface area. It is composed of one or more layers or horizons lying approximately parallel to the surface of the earth. A vertical section through these horizons is called the soil profile. Areas of soil having similar profile characteristics are designated by certain soil types.

In Illinois a few soils have thin profiles, that is, profiles less than one foot thick. Other soils have profiles as thick as 5 feet or more. Profiles of most of our soils, however, range between about 3 and 4 feet.

A few soils, such as those derived from recently deposited sediments, may have only one significant soil horizon, while others may have as many as five or six. In general, the profiles of soils in Illinois are made up of four major horizons, commonly known as (1) surface (A_1 or A_p), (2) subsurface (A_2 and/or A_3), (3) subsoil (B_2, often including B_1 and B_3), and (4) substratum (C and/or D), as shown in the sketch. The surface, subsurface, and subsoil horizons taken together as a unit are called the soil solum.



In uncultivated, uneroded areas, the surface layer, or A_1, is usually the darkest horizon in the profile. It is black in some soils and various shades of brown or gray in others. It averages 2 to 3 inches thick in soils developed under deciduous forest natural vegetation and 6 to 10 inches thick in prairie-forest border or open woodland (park) soils and in some of our strongly weathered prairie soils. It usually averages 1 foot or more in the moderately weathered, dark-colored soils developed under tall grass prairie and slough-grass vegetation. Also, in undisturbed or virgin areas, the A_1 horizon is made up of small but easily observed soft crumb or moderately firm granular aggregates. Many of these structure aggregates are destroyed by cultivation, and the result is a more compacted surface soil layer. This plowed layer is called an A_p.

The subsurface (A_2 and/or A_3) horizon in well-oxidized (well-drained) soils is primarily yellowish-brown in color due to good oxidation and thorough diffusion of the iron compounds throughout the soil mass. In poorly oxidized soils the predominant color is light gray, with the iron compounds concentrated into firm brown to black pellets or concretions.

The A_2 (subsurface), where present, is usually the horizon of lightest color and lightest texture in the soil profile. In some soils in Illinois it is only an incipient, or very weakly developed, layer 1 or 2 inches thick. In other soils it is a very conspicuous, well-developed layer as thick as 1 foot or more. Where strongly developed, particularly on broad flats or other poorly drained areas, this A_2 horizon often exhibits a structure of horizontally developed thin plates.

Some of our important dark-colored cornbelt soils do not have an A_2 horizon. They therefore have only three major soil horizons, the A_1 grading gradually through a thin subsurface transition zone or A_3 directly into the subsoil or B horizon below. Although the absence of an A_2 horizon does not necessarily indicate a fertile, productive soil, the presence of a well-developed A_2 indicates that that soil is somewhat low in organic matter, that it is probably acid and low in important plant nutrients, particularly in the A_2 horizon itself, and that a slowly permeable layer is probably present beneath it, as either a strongly developed subsoil or a substratum layer high in clay.

In most of the soils in Illinois the main subsoil, or B_2 horizon, is the zone of greatest clay accumulation. In general it is the layer of finest (often called "heaviest") texture. Two minor subsoil horizons are often present, a B_1, or upper transition zone from the A above, and a B_3, or lower transition zone into the C below. These horizons, where present, are usually lighter textured than the B_2 and may also differ from it in color or structure.

Soils that have formed in wet, swampy places usually have an accumulation of organic matter in the subsoil. Also, some of our older, imperfectly to poorly drained soils have a slight accumulation of organic matter or humus in the upper part of the subsoil. This organic matter is often in the form of coatings on the aggregate faces. In these latter soils the organic matter has been removed from the A horizons above and redeposited in the subsoil. The amount of dark organic matter, however, is usually not enough to cover up the gray, yellow, and brown colors of the oxidized or partially oxidized mineral compounds.

Color of the subsoil is the best indicator of soil oxidation, which is often termed "natural drainage." Where gray dominates throughout the whole horizon, the soil is poorly oxidized and is said to be naturally "poorly drained." (This use of the term "poorly drained" in soil profile descriptions does not necessarily indicate the permeability of the soil or the degree to which it can be adequately drained artificially.) Where the subsoil is a uniform bright yellowish-brown, it is well oxidized or is said to be "well drained." Mixtures or mottles about 50 percent gray and 50 percent yellowish-brown indicate partial or imperfect oxidation, and the soil is said to be "imperfectly drained" or in the past was often called "moderately drained."

The kinds and arrangements of soil aggregates are also distinguishing features of the subsoil in most soils in Illinois. Subsoils with slight clay accumulation have weakly defined aggregates of mixed sizes and shapes. As weathering continues and more clay accumulates, the aggregates become better defined, tending to form into distinctive sizes and shapes according to position in the horizon, amount of clay present, and natural drainage. Deposits of clay and silica flour accumulate on the aggregate faces, and the interstices eventually become the primary channels of water movement and root penetration. A soil horizon that is high in clay, very hard when dry, and very plastic when moist, that has tightly packed overlapping angular aggregates, and that is very slowly permeable is called a claypan and is often spoken of as "tight" clay.

The substratum may be composed of unaltered or slightly altered material, the same as that from which much or all of the solum (A and B horizons) was formed.

Material of that nature is called parent material, or C horizon. If the substratum is composed of material that is distinctly unlike the material from which the solum was developed, it is called D horizon.

Soil profiles may have either a C horizon or a D horizon or both. Where both are considered as part of the profile, the parent material, or C horizon, must be thin enough to make the unconforming D horizon material significant to the genesis of that soil or to its use and management. In Illinois D horizon material usually consists of limestone, sandstone, or shale bedrock, water-deposited materials that are significantly coarser or finer textured than the parent material, or fossil soil horizons in Illinoian glacial drift. Many of these materials are found in unexpected places in the state, although weathered Illinoian drift is most important in the thin loess areas to the south and west of glacial drift of Wisconsin age.

Many soil profiles often contain one or more other horizons in addition to those mentioned above, as well as some subdivisions of the major horizons. Deposits of organic debris on top of the soil surface are labeled A_0 if partially decomposed and A_{00} if undecomposed. Sometimes intensely reduced material--that is, material that has been under water for a long period, untouched by oxygen--is present. Such a layer is rather uniformly gray and is referred to as a G horizon. It may replace part or all of the subsoil.

Also in some soils, particularly in the southern third of the state, a dense, very slowly permeable, compact silt loam layer has developed as part of the lower subsoil and upper C horizon. This layer is very hard and brittle when dry but, because it is low in clay, it is friable when moist. This horizon is known as a siltpan or fragipan in contrast to a claypan, previously described.

A considerable number of soils in Illinois have developed from more than one parent material. Part or all of the A horizons are formed from one material, whereas part or all of the B horizons are formed from a different material. This is the situation throughout much of the northeastern part of the state, where 10 to 30 inches of loess covers glacial till, outwash sediments, and other materials. This is an important feature to observe in studying soil profiles, because the lower parent material often has much less favorable physical properties than the upper and may actually control the developmental processes of the soil as well as its agricultural usefulness.

H. L. Wascher
1-10-55

NATURAL SOIL DRAINAGE AND ITS INFLUENCE ON SOIL MANAGEMENT PRACTICES

Natural drainage in soils refers to changes in the moisture status throughout the soil profile (to a depth of 40 inches or more) under natural landscape conditions. Soil drainage is the result of many interrelated conditions, such as the amount of rainfall, amount of water lost by evaporation, water losses by plant transpiration, amount of runoff, permeability of the soil to water and air, and depth to the water table.

Since, in humid regions, these conditions vary with the seasons, the amount of water in soil tends to fluctuate. Natural soil drainage is concerned with these fluctuations, the frequency and duration of the periods when the soil is not saturated with water, and the rapidity and extent of removal of water from the soil in its natural state.

Natural drainage of soils, during their development, is reflected in certain morphological features, particularly color. It should not be confused with alterations in drainage, such as lowering of the water table by streams cutting back or by such man-made changes as tiling and ditching that have not operated for a sufficient time to change the morphology or appearance (chiefly color) of the soil.

Color is useful in inferring soil drainage conditions because, in general, soils tend to develop characteristic colors and color patterns under given drainage conditions. Where the color is not masked by dark organic matter, poorly drained soils tend to be gray because the iron is in the reduced or ferrous state. Well-drained soils, in which less water and more oxygen are present, tend to have less hydrated, more highly oxidized and more diffused iron compounds that give them a uniform brown or reddish-brown color. Intermediately drained soils usually have mottles or mixtures of gray, yellow, and brown.

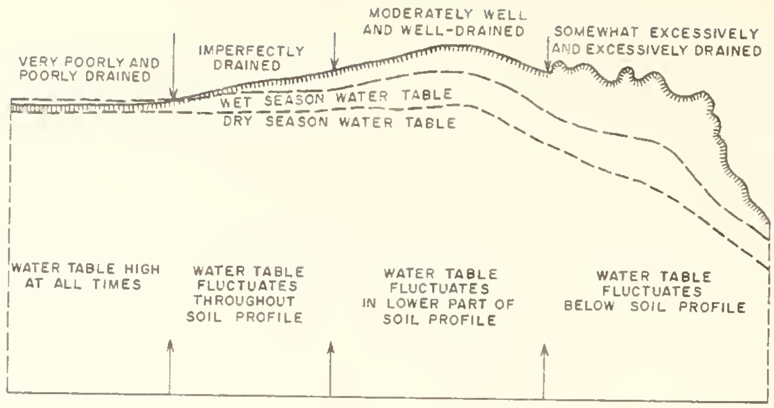
Besides color, other features that are useful in appraising or estimating soil drainage conditions include slope of the land and texture and structure of the various horizons in the soil profile.

In addition to these soil features from which soil drainage conditions can be inferred, the direct effect of the moisture status of the soil on plant growth is useful in classifying soils into natural soil drainage classes. At present there are seven natural soil drainage classes in use. They are very poorly drained, poorly drained, imperfectly drained, moderately well-drained, well-drained, somewhat excessively drained, and excessively drained soils.

From the practical standpoint of influence of natural soil drainage on soil management practices, chiefly water management, these seven classes may be combined into four groups, the first of which would include very poorly drained and poorly drained soils; the second, imperfectly drained; the third, moderately well and well-drained; and the fourth, somewhat excessively and excessively drained.

In soils developed from <u>medium-textured, moderately permeable</u> parent materials, such as silt loams and loams, there is a reasonably good correlation between slope and natural soil drainage. This relation is illustrated in the diagram on the back. In general, with <u>finer textured</u> materials, poorer drained soils occur on greater slopes; and with <u>coarser materials</u>, well-drained soils occur on lesser slopes.

The first practical management group of the natural soil drainage classes, the very poorly and poorly drained soils, for the most part, includes low-lying, depressional to flat, soils in which the water table is at or near the surface



RELATIONSHIP OF SOIL DRAINAGE CLASSES IN MEDIUM-TEXTURED MATERIALS TO SLOPE AND WATER TABLE UNDER NATURAL CONDITIONS

during much of the year. The high water table may be due to the low-lying position, to an impermeable layer within the profile, to seepage, or to a combination of these conditions. The soils of this group are predominantly gray in color, although some have dark surfaces. A few yellow mottlings or spots are common in the gray subsoils, and iron concretions are usually present. In most seasons these soils are too wet for good crop growth. They must be artificially drained with either tile or ditches.

The second group, the imperfectly drained soils, have fluctuating water tables that are high for long enough periods each season to give a mottled gray, yellow, and brown color to their subsoils. Surface horizons are usually more brown than are those of the very poorly and poorly drained group. Although the soils of this group commonly occur on gentle slopes, effective natural drainage is slow enough to restrict growth of field crops. Artificial drainage is needed, but not so critically as on the soils of group 1. Some imperfectly drained soils, especially the more sloping ones, require some erosion control measures as well as drainage.

Moderately well-drained and well-drained soils make up the third group. Because of somewhat restricted water movement, moderately well-drained soils are wet for a short but significant part of each season. They usually have a uniform brownish or yellowish color in the surface and upper part of the subsoil and a mottled gray, yellow, and brown in the lower part of the subsoil. Well-drained soils are those in which water is removed readily but not rapidly. They generally have a uniform brown or yellowish-brown color throughout their profiles. Well-drained soils tend to retain optimum amounts of moisture for plant growth. Moderately well and well-drained soils usually, although not always, occur on steep enough slopes to make erosion a serious menace unless appropriate soil-conserving practices are followed. Where soils of this group do occur on nearly level areas, they cause no serious water management problems because runoff is slow and underdrainage is adequate to remove excess water.

The fourth group, the somewhat excessively drained and excessively drained soils, are those from which water is removed rapidly to very rapidly. They are very porous and low in water-holding capacity, usually because of their low clay and high sand or gravel content, or their shallowness to porous layers of sand, gravel, or rock. These soils appear uniformly brownish or yellowish in color throughout their profiles. Because of low available moisture during much of the season, they are not well suited for the production of field crops. On these soils there is a definite need for water conservation practices.

J. B. Fehrenbacher
1-17-55

DEGREE OF WEATHERING AND DEVELOPMENT AFFECTS SOIL PROPERTIES AND MANAGEMENT PRACTICES

Differences in degree of soil weathering and development cause many of the important variations in Illinois soils, both regionally and on individual farms. These soil differences strongly influence productivity and management practices, such as drainage, fertilization, and cropping systems.

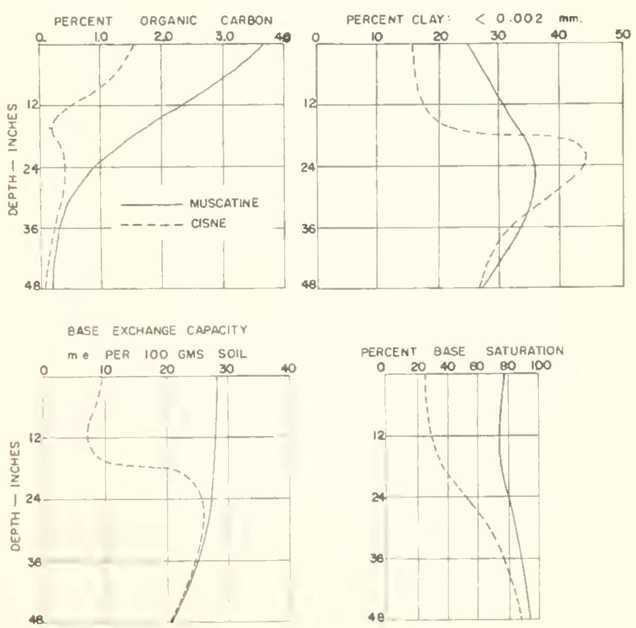
Soil development is due to the changing of minerals into different forms by weathering, movement of materials within the soil or removal from it, and the addition of certain materials, such as organic matter. Some important changes occur during the development of soils:

1. Bases, such as calcium, and other soluble materials are released from the minerals and may be taken up by plants or leached from the soil.
2. Easily weathered minerals decompose, leaving their residues along with the more resistant minerals.
3. Individual particles become smaller. Some of the fine clay particles are carried downward and accumulate in the B horizon or subsoil.
4. Organic matter accumulates primarily in the soil surface.
5. Layers or horizons develop in the soil, and a characteristic structure or aggregation develops in each horizon.

The kind, rate, and degree of development are determined by parent material, topography, native vegetation, time and climate, which are discussed in SP-1.

Important regional variations in Illinois soils that are due to differences in degree of weathering and development are illustrated by soils formed in different thicknesses of loess, a wind-deposited silty material. Muscatine silt loam, developed from calcareous loess more than five feet thick, occurs in western Illinois. Cisne silt loam, developed from thin loess averaging about three and one-half feet thick over strongly weathered Illinoian till, occurs in south-central Illinois.

Weathering and development are less intense in thick loess than in thin loess. In thick loess, frequent additions of large amounts of loess slowed effective weathering until the end of the loess deposition period, which is believed to have occurred about 12,000 years ago.[1] In thin loess, the material was deposited so slowly and in such small amounts that it was weathered during the deposition period (approximately 10,000 years), and weathering has continued since loess deposition ceased (approximately 12,000 years). Therefore, Cisne, which has been weathering for about 22,000 years is more strongly weathered and developed than Muscatine, which has weathered effectively for only about 12,000 years. The following graph shows some of the differences between Muscatine and Cisne soils.



In Cisne much of the organic matter that had once accumulated in the surface has been dissipated. The surface soil is

1/ Suess, H. E., U. S. Geological Survey Radiocarbon Dates I Science, Vol. 120, No. 3117, September 1954.

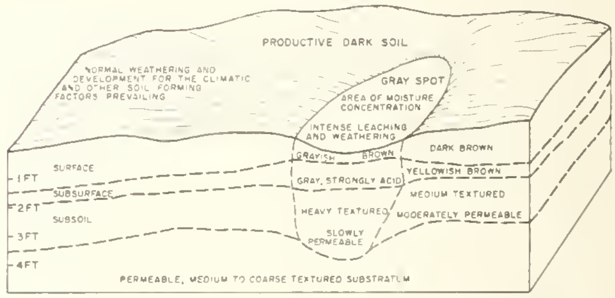
only moderately dark, and the subsurface is gray. Basic cations have been removed to a great extent, causing a strongly acid condition and a low base saturation. Clay has formed and most of it has become concentrated in the subsoil. The high clay content of the subsoil causes it to be so slowly permeable that water and air do not move freely in it. Surface ditches for drainage and large amounts of fertilizer are needed to produce satisfactory crop yields. On poorly drained areas such crops as alfalfa, which require good drainage, are difficult or impossible to produce.

In contrast to Cisne, Muscatine is naturally highly productive. It is characterized by a high organic matter content in the surface horizon, a high exchange capacity that is well saturated with bases and a permeable subsoil. The few limitations that this soil has are easily corrected.

In Illinois six stages of weathering are recognized in soils developed from loess (see SP-5). Muscatine and Cisne represent the second and sixth stages respectively.

Marked <u>local variations</u> in Illinois soils that are due to differences in the degree of weathering and development are illustrated by gray spots alongside darker colored soils in the same field. The gray spots are usually small and occur in slightly depressed areas. They are called gray spots because the surface, when bare, appears much more gray than the surface of less weathered soils around them. Gray spots are more noticeable and numerous in association with dark-colored soils developed under grass than with light-colored, forested soils.

Since the strongly weathered soils (gray spots) usually occur in slightly depressed areas, they receive large amounts of runoff from the higher surrounding soils. This concentration of water has the same effect as abnormally high amounts of rainfall on the leaching and weathering processes. In addition, these gray spots are normally underlain with medium- to coarse-textured, rapidly permeable substrata which allowed the water to pass readily through the soil in the early stages of weathering and soil development. These conditions favored rapid removal of soluble salts and accelerated weathering, as indicated by the following diagram.



The soil characteristics developed under these conditions are very much the same as those in Cisne soil. These soils have the following characteristics in contrast to their associated soils:

1. The immediate surface is low in organic matter; the subsurface is even lower in organic matter and quite gray in color.
2. Unless limed and fertilized, the soil is strongly acid and low in available plant nutrient elements.
3. There is a pronounced concentration of clay in the subsoil, and a resultant slow permeability.

Several soil types that are referred to as gray spots have been established in Illinois. Some of these soils are Denny, Thorp, Brooklyn, and Dunkel silt loams and Milroy sandy loam. They vary in degree of development, in parent material, and in drainage characteristics.

B. Ray
1-31-55

LOESS DISTRIBUTION IN ILLINOIS AND ITS AGRICULTURAL SIGNIFICANCE

Loess is a soil parent material. About 70 percent of the soils in the state are formed wholly or in part from this material.

Loess is normally a buff-colored, wind-laid sedimentary deposit consisting mainly of particles of silt size (.002 to .05 millimeters in diameter). It is nonstratified, homogeneous, calcareous, and porous. It may also possess a weak vertical structure resembling jointing.

Loess is one of the best soil parent materials in the state. These are some of the reasons:

1. Water is able to penetrate rather easily. At the same time the soil will hold large quantities of water available for plant growth.

2. Loess contains a high proportion of potassium, phosphorus, and other elements essential for plant growth.

3. Soils developed from loess are usually easy to cultivate.

4. Soils developed from loess tend to erode less than soils developed from heavier textured parent materials on equal slopes.

The origin of loess is associated with the Pleistocene or Ice Age, a period when vast continental glaciers covered the northern part of the United States. As these huge ice masses moved, they eroded hills and filled valleys, and during this process they ground up much of the mineral material into fine "rock flour." Streams flowing from the melting glacier front picked up some of this "rock flour" and later deposited it in the flood plains of the major outwash streams. During dry periods prevailing winds from the West and Northwest picked it up, transported it in an easterly direction, and finally deposited it at various distances from the source.

The major outwash streams in Illinois were the Mississippi, Illinois, and Wabash rivers. Wherever the flood plain of any of these rivers is quite wide, the loess deposited adjacent to it is deeper than where the flood plain is narrow (Fig. 1).

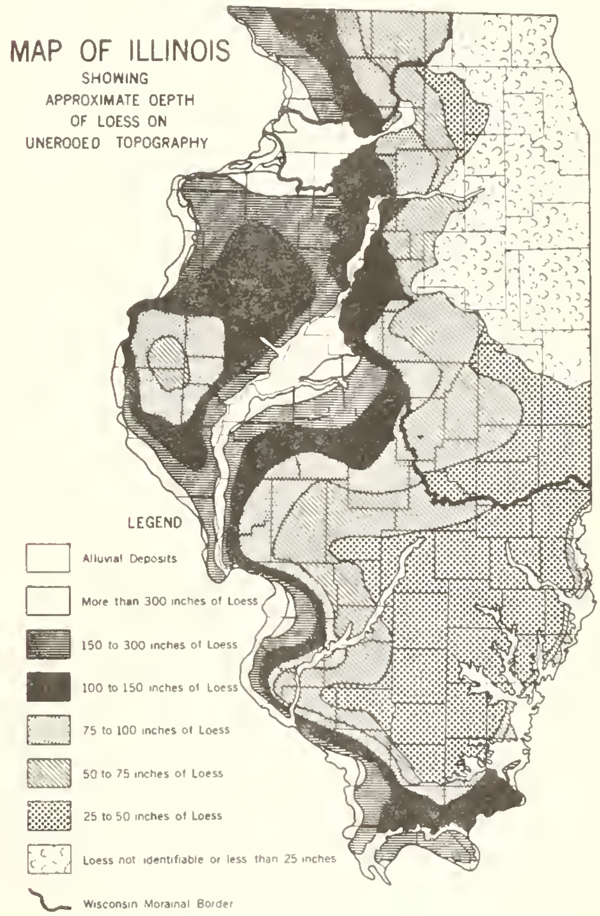


Figure 1

As would be expected, the loess in the upland is thickest nearest the source area and becomes increasingly thinner away from the source. Figure 2 shows thickness in relation to distance. The depth decreases rapidly in the first few miles from the source area, and then the rate-of-change decrease slows down as the distance increases. Accompanying this change in depth is a change in the mean particle size of the silt. The largest mean particle size is found

nearest the source, and the smallest at the farthest distance from the source.

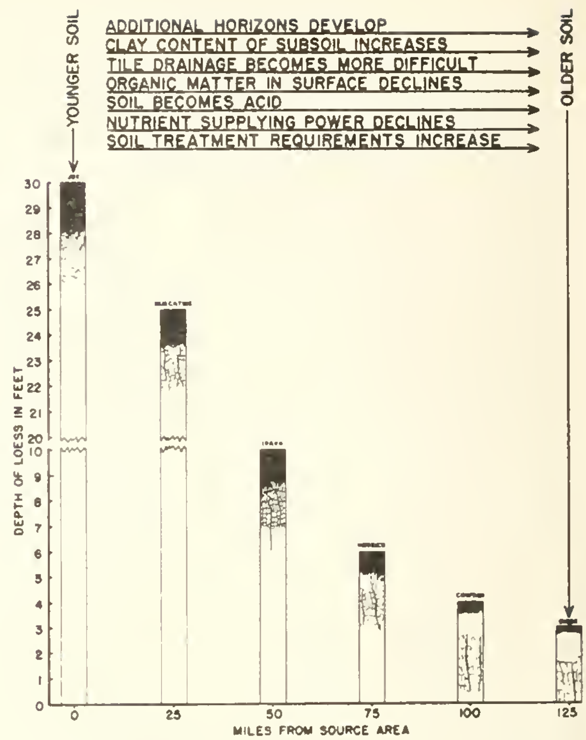
Also, as loess depth decreases, a change in type of soil occurs that is due primarily to intensity of weathering. For example, while one inch of loess is being deposited 100 miles from the source, ten inches may be accumulating near the source. With the same kind and amount of weather (rain, freezing and thawing, sunshine, wind, etc.), the one inch will of course be more strongly weathered than the ten inches.

As a result of this condition, we recognize in Illinois groups of soils called "Maturity Sequences." These soils are alike because they were formed under similar vegetation and climate from similar loessial parent materials on similar slopes (see Fig. 2). They differ only in depth and in intensity of weathering.

For example, in one of the "Maturity Sequences" the names of representative silt loam soils in each of the six groups are Joy, Muscatine, Ipava, Herrick, Cowden, and Cisne in order of increasing degree of weathering. This particular sequence was formed under grass vegetation on gentle slopes. Other sequences vary in degree of slope and type of native vegetation.

The soils mentioned in Figure 2 are not always found at exactly the stated distances, but occur over ranges in distance. Joy, Muscatine, and Ipava occur over wider variations in loess depth than do Herrick, Cowden, and Cisne.

Joy has no developed textural subsoil, while Cisne has a quite heavy-textured subsoil. Water penetrates the Joy profile easily, while in Cisne it penetrates very slowly. Tiling of Cisne is therefore not recommended, and excess water is removed by shallow ditches.



LOESS DEPTH IN RELATION TO INTENSITY OF WEATHERING

FIGURE 2

Productivity declines as the soils become more intensely weathered. Long-time average corn yields range from about 70 bushels an acre on Joy to about 45 bushels on Cisne. This decline is due to the greater leaching of essential plant nutrients from the soil, the decline of organic matter, and the increasingly less desirable water relations that prevail. As the older soils become less productive, rather large amounts of lime, potash, phosphorus, and nitrogen must be added in order to produce crops economically.

Because some of the younger soils, such as Muscatine, have been intensively cultivated, they too have reached the stage where moderate additions of lime, phosphate and, to a lesser degree, potash and nitrogen are needed in order to produce high yields.

J. D. Alexander
2-21-55

A FIRST LOOK AT SOIL AERATION

Air in the soil might be considered the "draft control" over the chemical and biological processes or "fires" that are "burning" in the roots of the growing plant. Growing, respiring roots require a source of oxygen and a "chimney" to eliminate carbon dioxide. The ability of the plant root to get enough oxygen from its immediate environment and to release carbon dioxide determines whether it lives well or dies of "suffocation."

Is the air in the soil different from the atmosphere above the soil? Generally the soil air contains more carbon dioxide and less oxygen than the normal air. The composition of the normal atmosphere is about 79 percent nitrogen, 20.3 percent oxygen, .03 percent carbon dioxide, and .67 percent miscellaneous gases. The sum of carbon dioxide and oxygen contents remains about the same in soil air as in normal air, but in the soil air the oxygen content may be reduced to 15 or 18 percent and the carbon dioxide content increased to 2 to 5 percent. A 50-fold increase in carbon dioxide content may not be uncommon. The oxygen content decreases and the carbon dioxide increases with depth.

Since oxygen that is used by the respiring roots and microorganisms comes from the air above the soil and the carbon dioxide produced by the root must largely return to the atmosphere, the rapidity of this exchange is obviously important. What physical conditions affect this exchange?

Changes in barometric pressure, rainfall, and velocity of the wind may account for a small part of the total exchange, but by far the most important mechanism of gas exchange is diffusion, a process that tends to equalize the concentrations of the various gases between the soil air and the atmosphere. The rate of diffusion depends primarily on the amount of air-filled pore-space in the soil; i.e., diffusion is most rapid in the most porous soils. Therefore, if we can measure the porosity of a particular soil horizon and can measure the concentration of oxygen or carbon dioxide at a particular depth, we can estimate the rate at which carbon dioxide will diffuse from the soil into the atmosphere. By way of illustration, if, at a depth of 10 inches, the soil air contains one percent of carbon dioxide and the soil has a porosity of 30 percent, approximately 1,600 cubic feet of carbon dioxide gas will diffuse from an acre of soil per day.

What are the consequences of an insufficient rate of gas exchange between the soil and the air above it? In the soil either or both of two situations may develop: The concentration of oxygen may fall to a deficient level, or the concentration of carbon dioxide may rise to a toxic level. Also, above the soil, in the air where the plants are using carbon dioxide in photosynthesis, a shortage of carbon dioxide may develop if the diffusion rate is too slow.

What concentration of oxygen in the soil air represents a deficient level? This is difficult to define for two reasons. One is that we do not have good enough instruments to measure the oxygen or carbon dioxide content where it is important--at the surface of the root. The second is that different plants have different tolerances. However, by varying the oxygen content of air that fills the pore space of sand or soil surrounding an experimental plant or by bubbling air of varying oxygen content through a culture solution, we can produce deficiency effects.

It has been found that in general a low oxygen content--less than about 5 percent--has two effects: (1) the permeability of the root for water is decreased,

and (2) the absorption of nutrients is reduced. Restricted aeration of corn roots has been found to reduce nutrient absorption in the following order: potassium, calcium, magnesium, nitrogen, and phosphorus. Since the concentration of nutrients is higher within the plant root than in the soil, energy must be supplied in order that the nutrient elements may diffuse into the root cell. Oxygen is the vital link in the energy mechanism.

It should be noted further that, while the oxygen content of the soil air does not in general fall to a level as low as 5 percent, there may be areas within the soil mass surrounding the root system where deficiency levels will occur.

A parallel question is: What is a harmful concentration of carbon dioxide in the soil? A considerable amount of research indicates that a concentration greater than about one percent may be harmful to plant roots, depending somewhat on the oxygen level. The effect of high carbon dioxide content is to reduce water and nutrient absorption. The harmful effect of carbon dioxide is attributed to a change in the internal pH of the cells.

We have mentioned that a restricted gas exchange may result in a deficiency of carbon dioxide in the air immediately above the soil. Observations made in fields of tasseled corn throughout the day and night have shown that the level of carbon dioxide may be reduced by one-fourth below the average daily composition. This fall occurs at the height of photosynthetic activity shortly after mid-day. Fluctuations in the carbon dioxide content from day to night varied from .04 percent to .02 percent, with .03 percent assumed to be normal. It has been estimated that photosynthesis may be just equaling transpiration losses at about a .01 percent carbon dioxide concentration. Therefore, it is quite possible that a concentration of .02 percent reduces photosynthetic activity and may limit corn yields.

Finally, what are the cropping, cultural, and manurial practices that will bring about a desirable rate of gas exchange? Since waterlogged soils have very limited pore space, any measure that will prevent this condition is desirable, such as tiling and open ditches to remove excess water or, if irrigation is employed, controlled water application. Compacted soil horizons obviously reduce the rate of diffusion; therefore, the use of fertilized crops that will develop heavy root systems and the application of organic residues are necessary to maintain well-aggregated soil horizons.

"Sealed" soil surfaces may essentially stop oxygen and carbon dioxide exchange. Referring to the previous figure of 1,600 cubic feet of carbon dioxide production per acre per day, one can estimate that, if a "sealed" surface developed on this acre, possibly caused by a rain which prevented gas exchange, the carbon dioxide in the top 10 inches of soil would double in an hour and a half and would increase 15 times in 24 hours. This estimate assumes that root respiration and microbiological activity would continue at the "unsealed" rate, which is not quite a true assumption.

One of the prime benefits of manure is that it increases the microbiological activity of the soil. It is estimated that in a well-manured soil 30 percent of the carbon dioxide is produced by growing plant roots and 70 percent by microorganisms. Thus the amount of respired carbon dioxide is increased by manuring. If, as indicated earlier, there is a possibility of a carbon dioxide deficit at the height of photosynthetic activity, plants growing in well manured soils should suffer least.

An important objective of all cultural practices should be to maintain or build up a condition of stable soil aggregation in as much of the rooting zone as possible. Otherwise the optimum rate of soil-air gas exchange cannot be attained.

R. H. Rust
3-14-55

GLACIAL TILL OF WISCONSIN AGE IN ILLINOIS

In northeastern Illinois, in that part of the Wisconsin till region where the loess cover is less than 2 to 3 feet thick, neighboring farmers often get a 50 percent difference in yields of the common corn-belt crops. On other nearby farms in the same region, 100 percent yield differences are not unusual, and the farmers do not always know why. Air and water relationships in the soils differ significantly, causing similar cropping, erosion control, fertilizer treatment, and other management practices to have widely differing effects.

Soils formed from till of Wisconsin glacial age are not highly weathered, nor are their profiles strongly developed. Calcium carbonate is usually present at a depth of 3 1/2 feet or less in sufficient amount to effervesce or bubble with weak hydrochloric (muriatic) acid. Magnesium carbonate is often present within a depth of 2 feet, and most other primary minerals are relatively undecomposed. The soils are still relatively young; they may be classified as about the "adulthood" stage of development (see SP-1).

Some of the soils have developed under a deciduous hardwood forest vegetative cover. They are light colored in the surface and low in organic matter. Others have developed under prairie vegetation, and they have deep, dark-colored surfaces that are high in organic matter. These surface color differences are easy to see and easy to recognize because they occur in the plow layer. But there are some differences in the subsoil and substratum that are not so easy to recognize, and they are the ones that concern us here.

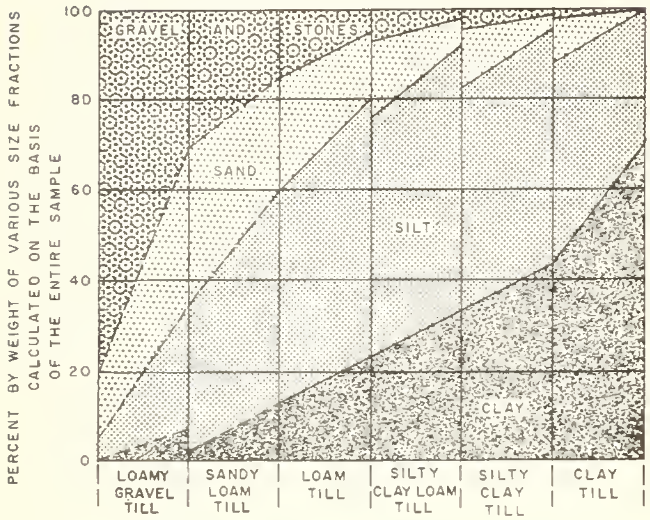
Among soils in this region that developed under the same kind of native vegetation, differences in productivity and response to treatment, in erosiveness, in drainage needs, and in effectiveness of tile, as well as in many soil profile characteristics, are due primarily to variations in the character of the glacial till from which the soils developed. These differences are a result of varying kinds and amounts of rocks and minerals in the till.

Detailed soil survey studies have shown that the unleached glacial till in this part of Illinois varies in texture or mechanical composition from coarse loose gravel and cobbles to fine clay (see Figure 1). It varies gradually and almost continuously from more than 75 percent gravel with little or no clay, through various combinations of gravel, sand, silt, and clay, to nearly 75 percent clay with little or no gravel.

Limestone is predominant throughout the entire range of till textures, making up more than 60 percent by weight of the material coarser than 2 mm. (about 1/12 inch). The coarser textured tills contain the most igneous and metamorphic (crystalline) rocks and the most sandstone. The finer textured tills contain the greatest amount of shale.

On the basis of these studies, six textural groups or classes of calcareous glacial till were established that can be determined in the field and that are of practical as well as scientific importance. These six groups are (1) loamy gravel (and coarse sand) till, (2) sandy loam till, (3) loam (and silt loam) till, (4) silty clay loam till, (5) silty clay till, and (6) clay till (see Figure 1).

FIG. I. THE APPROXIMATE RANGE IN MECHANICAL COMPOSITION OF CALCAREOUS GLACIAL TILL OF WISCONSIN AGE IN ILLINOIS



These differences in till texture determine many soil profile as well as many soil and plant relationship differences. Varying profile characteristics are produced directly from the tills as soil parent materials, and indirectly by the effect of the till textures on the air and water relationships in the soils.

The tills of loamy gravel texture absorb rainfall rapidly but retain little of it for rock and mineral weathering or for plant use. Leaching is slow because drainage water moves too rapidly to permit maximum dissolving action, and also because the rock fragments are large. As a result, many limestone pebbles still occur within the top few inches of the till.

Soils that are developed wholly or partially from loamy gravel till are well drained or well oxidized even on flat areas, unless some other factor keeps the water table at a high level. Areas in which the loose, gravelly till is shallow or exposed at the surface are drouthy and low in productivity. They are not well suited to tillage or the production of intertilled crops. Such areas are best adapted to grass, to the early maturing small grains, or sometimes to trees.

The clay-textured tills, at the other extreme, absorb rainfall slowly. They may retain a great deal of water, but downward movement is so slow that the soil surface is quickly saturated and runoff is high. Leaching is extremely slow because little or no water from normal rainfall finds its way through the clay till to underground drainage outlets. Dissolved carbonates are precipitated more or less in place as soil moisture evaporates or is removed by plants. Limestone particles are present in the top few inches of the till.

Soils developed from clay till are imperfectly to poorly oxidized even on slopes. Tile are ineffective, and plant root penetration is often limited to the upper soil horizons. Areas in which the clay till is shallow or exposed at the surface are nearly impossible to farm and are very low in productivity. No crop plants or native plants do well on the exposed calcareous till, and few have been known to even survive for any length of time.

The tills of medium texture (loam and silt loam), on the other hand, absorb rainfall freely. They retain enough water for good plant growth but permit the excess to drain away readily to tile or other underground outlets. Leaching is relatively rapid, and few limestone pebbles remain within the upper foot of till. Released plant nutrients are abundant.

Soil drainage or oxidation is related directly to slope; i.e., poorly oxidized soils occur in undrained depressions, imperfectly oxidized soils occur on nearly level areas or low knolls and ridges, and well oxidized soils occur on moderate to steep slopes and high, narrow ridgetops. Plant root penetration is unrestricted, and soil areas where unweathered till is shallow or even exposed at the

surface are not hard to farm and, if properly fertilized, produce excellent crops.

Soil profile features, productivity of the common corn-belt crops, and use and management requirements of soils developed from till of sandy loam texture vary between those for loam till soils and those for loamy gravel till soils. Profile characteristics, productivity, use and management features of soils developed from tills of silty clay loam and silty clay textures vary between those for loam till and clay till. Thus it is easy to see that without the cover of loess on all of the various textures of glacial till in this region, except perhaps on loam and silt loam, the soils would be a great deal more different than they now are.

The important soil series established to date in Illinois whose profiles were derived partly or wholly from till of Wisconsin age are as follows:

	Soil			
Texture of till	Light-colored (forest)	Medium-colored (trans. forest-prairie)	Dark-colored (prairie)	Very dark-colored (wet prairie or slough grass)
Loamy gravel	Rodman, Fox	Dresden	Lorenzo, Warsaw	Troxel
Sandy loam	McHenry		Ringwood	Troxel, Drummer
Loam	Hennepin, Strawn, Miami	Herbert	LaRose, Saybrook, Lisbon	Drummer, Peotone
Silty clay loam	Morley, Blount	Beecher	Varna, Elliott	Ashkum, Peotone
Silty clay	Chatsworth, Eylar	Frankfort	Swygert	Bryce, Rantoul
Clay	Chatsworth, Eylar		Clarence	Rowe, Rantoul

H. L. Wascher
5-2-55

CLAY MINERALS IN ILLINOIS SOILS

Clays perform several functions in the soil. Among the most important ones are the storage and exchange of nutrients for the growing plant and the storage and release of water. The clays also absorb organic constituents (see SM-7). The kind and amount of clay together with the absorbed ions determine to a large extent the chemical and physical properties of most agricultural soils.

Why are the clay minerals so much more active than the larger silt- and sand-sized minerals? There are two principal reasons for the unique chemical and physical reactivity of the clays: (1) the clay minerals are negatively charged particles, and (2) they contain a large amount of exposed surface per unit weight of clay.

The clay minerals have an inherent negative electric charge which is satisfied by positive ions absorbed on the surface. The amount of positive ions (some are plant nutrients) that one hundred grams of clay will hold or store is generally referred to as the cation exchange capacity. The clay will, however, trade or exchange the absorbed positive ions for any other positive ions that come along. This is the reason it is referred to as "exchange" capacity.

If too much hydrogen has been exchanged for the positive ions, liming becomes necessary. When an acid soil is limed, calcium and magnesium in the limestone replace the hydrogen, and the soil once again becomes neutral or sweet. Likewise, when potash is added to the soil in soluble form, it is stored on the clay minerals ready for use by the growing plants.

The large amount of exposed surface in a small amount of clay is due to the size of the clay particles and to their shape and swelling properties. The structure of most of the clay minerals is plate- or leaf-like, the plates being stacked together like pages of a book. There may be a thousand plates in one tiny clay particle.

In what are called the swelling clays, water and plant nutrients are absorbed on both sides of each plate that makes up a particle. A handful of this kind of clay may have over an acre of exposed surface on which plant nutrients and water are held.

In some kinds of clays the plates are rigidly held together, and these are referred to as nonswelling clays. Ions and water are not free to go inside each particle. In this type, the amount of exposed surface depends on the size of the particles. A handful of nonswelling clay may have only a few square yards of exposed surface. If the particles are very small, however, it can still have a large amount of exposed surface per unit weight. Each particular kind of clay mineral has characteristic and different cation exchange and swelling properties. For this reason it is important to know what kind of clays we have in our soils.

The soils of Illinois contain one or more of four principal kinds of clay minerals: kaolinite, illite, chlorite, and montmorillonite (Fig. 1).

Kaolinite is a relatively large, nonswelling, low base exchange capacity clay. It is not found in the till-derived soils in northeastern Illinois and is present only in traces in the loess-derived soils (see SP-5).

Illite is an important clay mineral in most Illinois soils. It has a cation exchange capacity about seven times that of kaolinite. The leaf-like plates in each small particle are held together

with potassium. It is therefore a nonswelling clay, but because of its small size it exhibits moderate plastic and sticky properties.

Illite comprises, on an average, 60 to 80 percent of the clay minerals (<0.002 mm. in diameter) in the soils in northeastern Illinois that have developed entirely from tills of Wisconsin age. In the soils developed from loess (about 70 percent of the soils in Illinois), the illite content in the B and C horizons averages 10 percent. The amount increases to approximately 35 percent in the A horizon of these soils.

Chlorite is present in most of the soils in Illinois. In the till-derived soils it varies in amounts but averages about 25 percent in each horizon. In the loess-derived soils it is about 20 percent in the A, and 10 percent in the B and C horizons.

Chlorite has about the same cation exchange capacity and plastic properties as illite. It is a nonswelling clay in which the sheets are held together with aluminum and magnesium instead of potassium.

Montmorillonite is the principal clay mineral in the loess-derived soils in Illinois, particularly in the lower horizons. It comprises about 80 percent of the clay in the B and C horizons but decreases to a little below 50 percent in the A horizon. This decrease is the result of evaluation or movement of this kind of clay to the lower horizons.

Montmorillonite is a swelling clay that has a cation exchange capacity 15 to 20 times larger than that of kaolinite. It is highly plastic and sticky when wet and shrinks upon drying. It has a higher water-holding and nutrient-storage capacity than any other kinds of clay minerals.

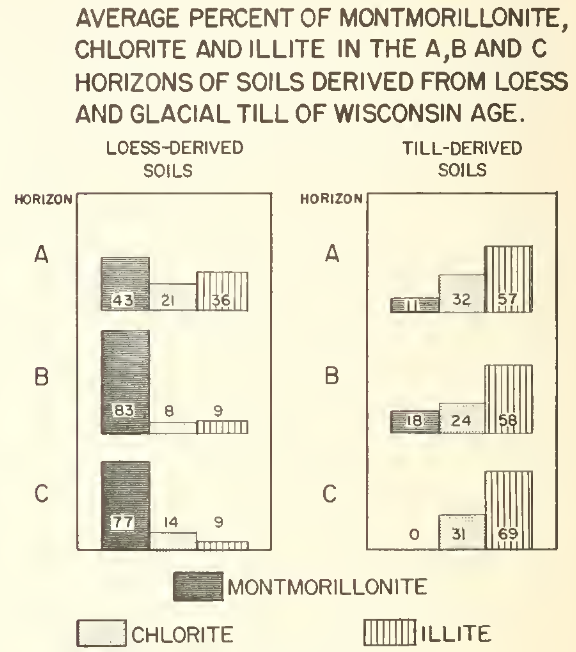


Figure 1

The clay minerals are vitally important in agriculture because of their tremendous chemical and physical influence on the plant root environment. There is an intimate relation between the plant root and the clay mineral. The growing root relies upon the clays for major sources of water and nutrients. This root-clay relationship in the soil ranks next in importance to photosynthesis in the growing of agricultural crops. It is therefore imperative that we understand the chemistry and physical behavior of the clay minerals.

A. H. Beavers
5-23-55

AGRONOMY FACTS

W-4

CONTROL OF CANADA THISTLE

Canada thistle is one of the oldest and most serious weeds we have in the United States. It is believed to have been brought to Canada by the French early in the 17th century and introduced into eastern New York in hay and grain in 1777 by the movement of Burgoyne's army. From there it spread rapidly westward. At present it covers all of northern United States and lower Canada.

This weed is a deep-rooted perennial that spreads both by underground roots and by seed. There are both male and female plants, and both must be present in order to produce seed. Isolated patches of either male or female plants may occur that will not produce seed, but these plants will continue to spread by the underground root system.

Seed is usually produced in the most northern part of Illinois, where there are thistles of both sexes and where climatic conditions are favorable for producing seed. Plants in central and southern Illinois do not always produce seed either because patches are isolated or because the climate is less favorable.

Because Canada thistles are cross-pollinated, the plants differ somewhat in appearance. We have some strains that, although they resemble Canada thistle, vary somewhat in leaf shape and other characteristics. The size and color of the flower are, however, usually uniform in all strains.

Like all perennial weeds, Canada thistle carries large food reserves in its underground root system. It uses some of this food early in the year to begin its top growth. But by the time the plants are eight to ten inches high, the parts above ground are manufacturing enough food to replenish the underground reserves. Therefore, if Canada thistle is to be controlled by cultivation, it should not be done until the plants are eight to ten inches tall (about one month after they emerge).

The reason for delaying cultivation is to allow the food reserves in the roots to become depleted by the early growth demands of the plant. After the first tillage, the plant takes more food from the roots; and if the thistles are cultivated every two or three weeks during the season, the reserves will eventually be exhausted and the entire patch will die.

The length of cultivation will depend largely on the vigor of the thistles. If a large amount of food has been stored in the roots, it may take two seasons to kill the plants. But if they have been weakened by previous cultivations one season's work may do the job.

Competitive crops are also useful in destroying thistles. A good, thick, vigorous stand of alfalfa is one of the best possible ways to control Canada thistle. Sweet clover is also an excellent smother crop. Early cultivation, combined with delayed planting of thickly planted soybeans, Sudan grass or millet, has also been effective.

Chemicals offer a good possibility for the control and eventual eradication of this weed. There are a number of soil sterilants that are effective. Sodium chlorate and Atlacide have been used for a number of years. The main objection to these soil sterilants, as well as others like them, is that the land

becomes sterile for at least a year, and usually two. In addition, they are expensive if used on large areas. But they are quite reliable and, if used according to directions, will usually insure a good kill.

2,4-D is another herbicidal treatment that has been widely used. It should not be applied until it can move into the root system with the translocated food from the leaves. The most sensitive stage of growth is when the thistles are approaching the early bud stage. Spraying before this time will not be effective, and spraying after the blossoms appear also usually has little effect.

An application of 2,4-D will usually kill the top growth for a period of four to six weeks, but after that time it will begin to grow again. A second application should be made when the thistles are six to eight inches tall, and a third one in the late summer or early fall if they begin to grow again. It is especially important to make second and third applications each year. If they are not made, the thistles will manufacture food rapidly and store it in the roots. If the plants are to be eliminated, this process must be stopped. The 2,4-D can often be applied even after heavy frost in the fall.

In general, applying 2,4-D for two years will either eliminate or reduce many patches of Canada thistle. Application cost is reasonable--about one dollar an acre for the chemical. Another advantage of using 2,4-D is that it is possible to grow a crop on the treated area during the eradication process.

Rates of application are fairly important. If the rate is too heavy, the 2,4-D will burn back the top growth too fast and it will not penetrate the root system sufficiently. In no case should more than one pound of 2,4-D acid per acre be used. 2,4,5-T or MCP has given no better results than 2,4-D when applied at comparable rates. If Canada thistles are sprayed in a growing crop, the rate and time of application may have to be adjusted to suit the crop.

Some strains of Canada thistle seem fairly tolerant to 2,4-D sprays, but so far there are only a few such strains. Experience indicates that it would be best to begin with a 2,4-D program and, if patches are still left after this treatment, to follow with clean cultivation or a soil sterilant to finish off the few patches that are left.

F. W. Slife
3-7-55

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE

AGRONOMY FACTS

W-5

CONTROLLING WEEDS IN SOYBEANS

Weeds present one of the greatest hazards to good yields in soybeans. This is true even though soybeans are used as a smother crop to control some of the more serious perennial weeds. Soybeans are excellent weed competitors if they germinate and grow rapidly to form a dense ground cover. But if the weeds germinate at the same time as the soybeans or if the beans germinate and grow slowly, the fields are likely to be very weedy.

Better weed control is the reason the soybean acreage in Illinois has been largely shifted to row planting rather than solid seeding. Although the companion crop could effectively use the shade provided by solid-seeded soybeans later in the season, we will probably continue to plant soybeans in rows until we find a good method of controlling weeds early in the year.

At present the best way to control weeds in soybeans is to use good cultural practices. Such practices include plowing and preparing the seedbed early in the spring in order to permit the weed seeds to germinate as soon as possible. From one to three crops of weeds can be destroyed before soybeans are planted. In fields that are known to be weedy, soybean planting should be delayed until the soil is warm enough to produce rapid germination. Soybeans are much more sensitive than corn to cool soils. If planting is delayed until the soil is warm, the beans will emerge quickly--usually before the weeds.

With this method we can use the rotary hoe to remove the weed seedlings before cultivating the soybeans. It is still one of the best implements for controlling weeds in soybeans provided it is used at the right time.

Soybeans should be cultivated as often as is necessary to control weed seedlings.

Use of furrow openers in the soybean belt has been increasing during the past few years. They seem to be particularly effective when the beans germinate and emerge before the weeds, because the dirt can be rolled in on the small weeds without injuring the beans.

Chemical weed control has not progressed so rapidly in soybeans as in some other crops because the beans have been quite sensitive to most chemicals. The two most promising ones for pre-emergence control in soybeans have been dinitro and chloro IPC. Both should be used at the rate of 6 to 8 pounds an acre on the heavier soil types. Neither should be used on light or sandy soils, and neither is recommended for general use because the results have been too variable. If the soil surface remains dry for ten days to two weeks, weed control will not be good. In a few cases, also, soybean stands have been thinned when heavy rains have washed the chemical down into the soybean germination zone.

Five years' experimentation with pre-emergence chemicals shows these two to be the best now available for pre-emergence control. However, because of their failure to control weeds in some years and because of reported crop injury in other years, both dinitro and chloro IPC are recommended only for trial use or for use in areas where weeds cannot be controlled by cultivation. There appear to be new and better pre-emergence chemicals for soybeans on the way.

After soybeans have emerged, 2,4-D is suggested for trial use in certain areas. On young soybeans a light rate of 2,4-D

amine should be used. Three years' tests show that 1/8 pound of 2,4-D acid in the amine form applied to beans 3 to 5 inches tall does not affect yield. This rate is sufficient to control cocklebur, annual morning glory, pigweed, and ragweeds. It will also affect lambsquarter, jimson weed, and smartweed, but it will not always kill them.

The 2,4-D treatment is not designed to replace cultural practices; it should be used only in an emergency when it is not possible to control weeds in any other way. It is especially effective in bottomland areas where cocklebur and ragweed present a problem.

Applications of 1/4 pound of 2,4-D acid in the amine form have reduced yields about 15 percent when applied to soybeans 3 to 5 inches tall. Use of this chemical on soybeans is therefore recommended only on a trial basis until farmers find out for themselves whether its effectiveness in controlling weeds will offset possible reductions in crop yield.

F. W. Slife
4-18-55